Brookhaven National Laboratory

U.S. DEPARTMENT OF ENERGY

Polarized Proton Operations in Run 22

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Overview

Polarized proton physics running

- Operational requirements
- Injector split/merge scheme
- RHIC spin resonance correction

Other developments and operating modes

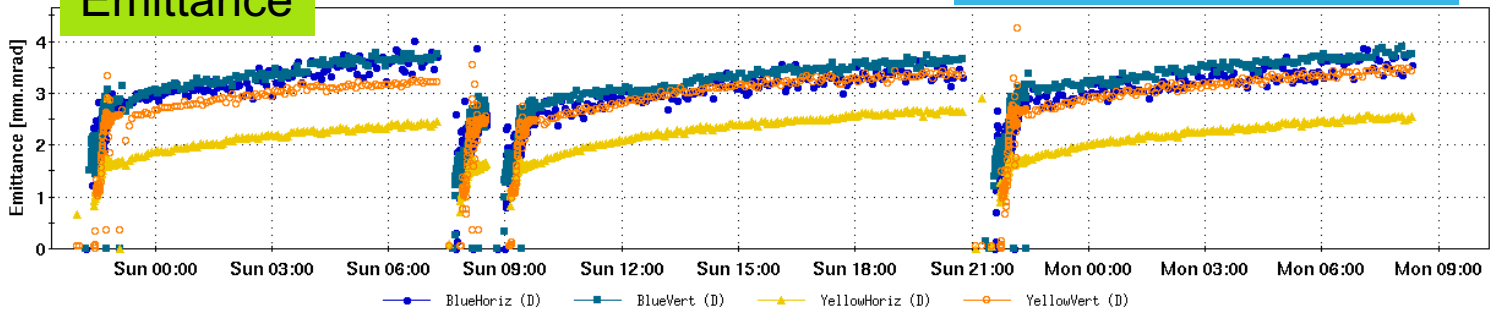
Operational schedule and plan

Polarized proton operation

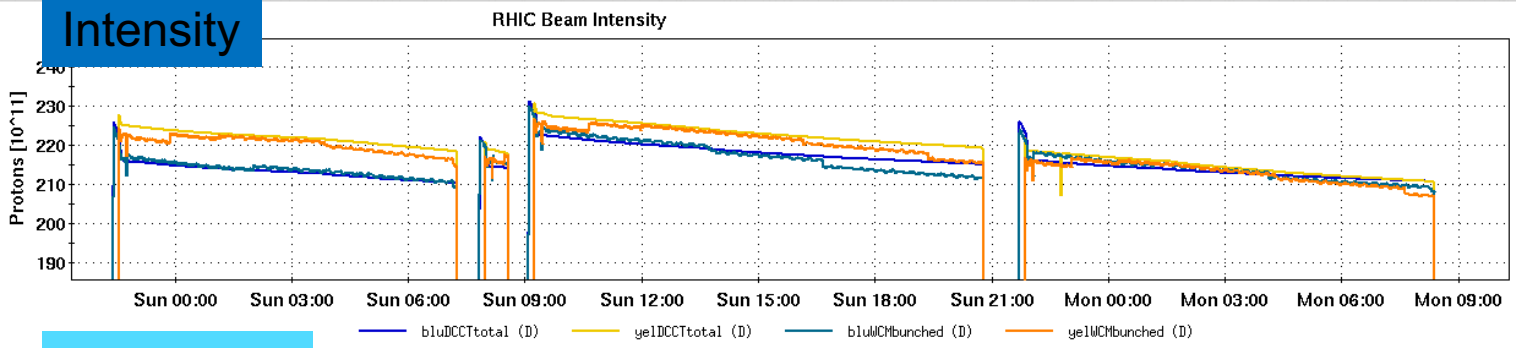
- Polarized proton collisions at 255 GeV
  - 16 weeks
  - + 2 weeks of CeC
- Conditions similar to Run 17
  - Collisions at IP6 only
    - Cogging: abort gap collision at IP8-2
  - Luminosity capped at 14×10^{31} $cm^{-2}s^{-1}$
    - (limited) Leveling via second beta*
    - No crossing angle/misteering
    - *Transverse polarization only (no rotators)*
- Operational RF:
  - Inject/accelerate: 9 MHz+Landau
  - Rebucket: 28 MHz
  - Store: 28 MHz + 197 MHz

Typical Run 17 stores

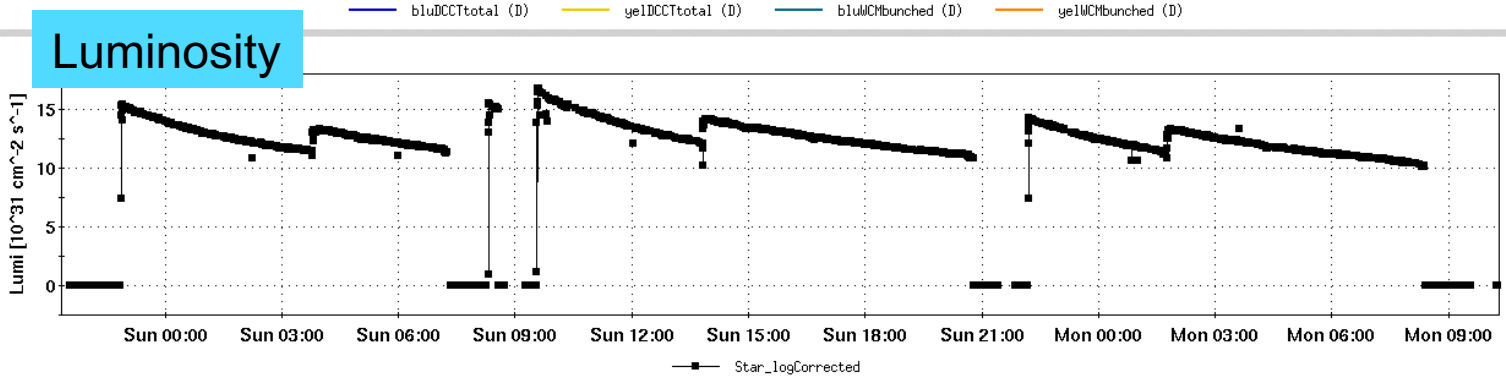
Emittance



Intensity

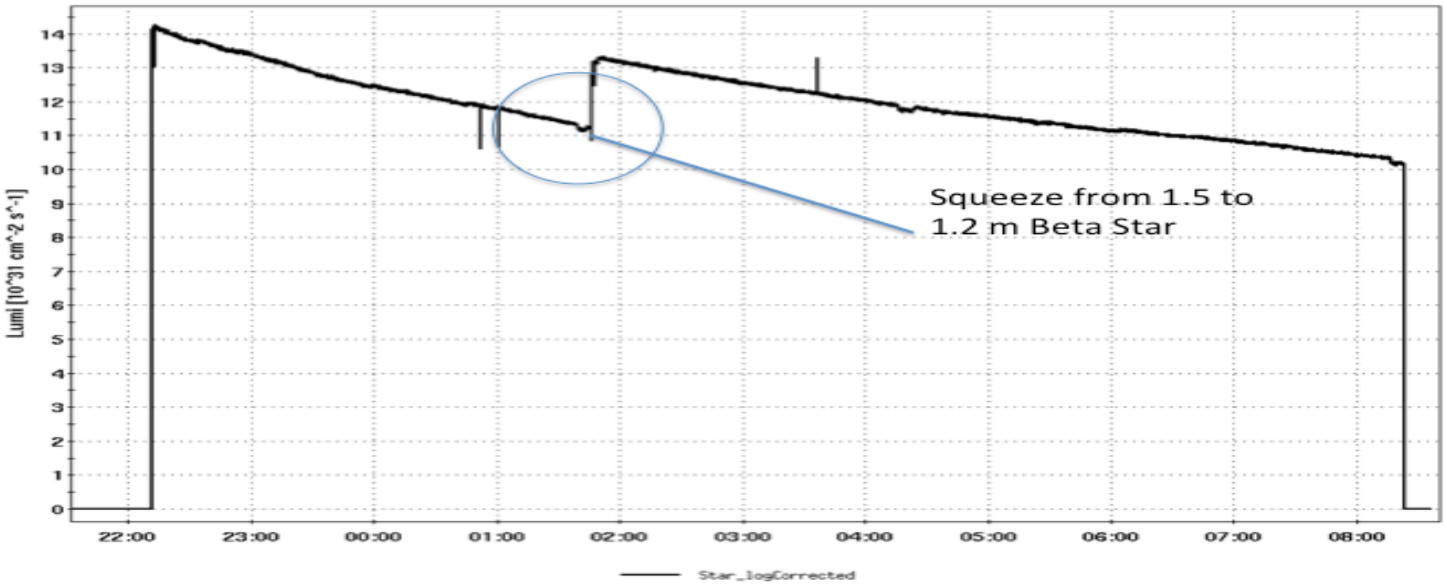


Luminosity



Typical Run 17 Store

	Start of store	
Intensity (/bunch)	2 x 10^{11}	
Emittance (trans,norm)	2.5	um,rms
Luminosity	14×10^{31}	$cm^{-2}s^{-1}$
Polarization (avg)	55%	



Polarized equipment, systems and software

- Polarimetry (Linac, AGS, RHIC)
- AGS (2) and RHIC (4) helical dipole snakes
- Polarimeter applications: polarControl, krisch sheet, SpinOrchestrator
- AGS tune jump quadrupoles, software, Ggamma meter
- AGS tune meter
- AGS transverse damper (vertical only)
- Booster tune meter and AC dipole
- …

Space charge at AGS injection

AGS has large space charge tune shifts at injection (intensity = 2.5 x 10^{11})

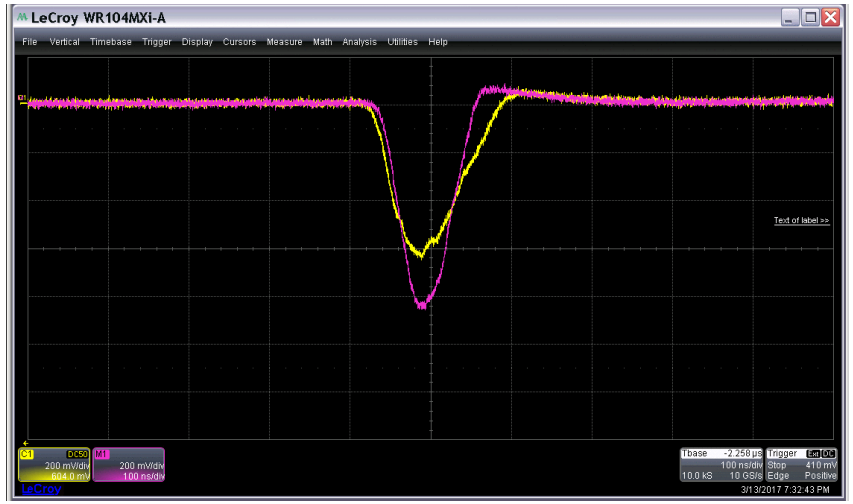
$\Delta Q_{sc}(x,y) = -0.17, -0.25$

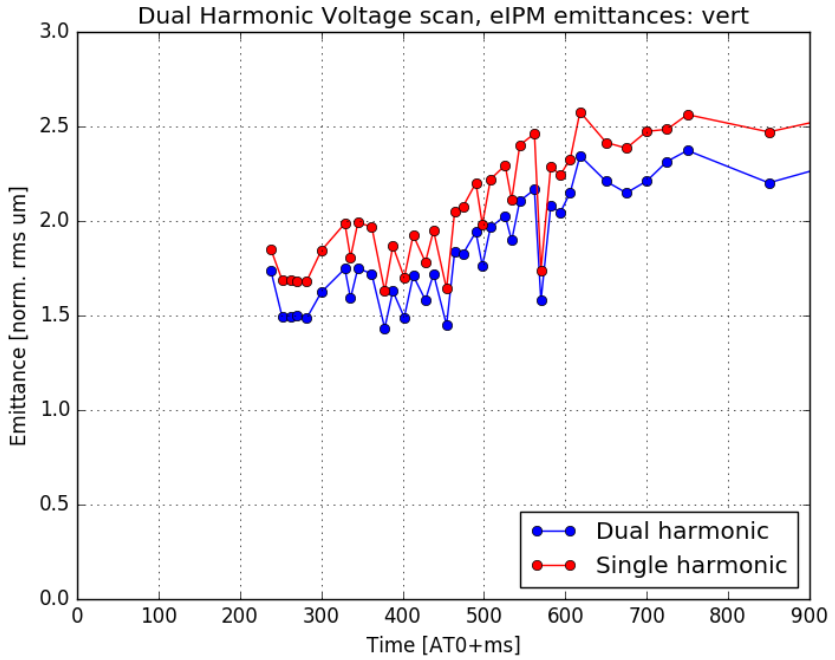
Run 17 operation:

Observations of peak current-driven emittance growth at low energy in AGS

- Added defocusing RF voltage:
  - Single bunch captured on h=6, defocused with h=12
    - 20% reduction in peak current
    - 15% reduction in vertical emittance

AGS Longitudinal distribution (WCM, inj. energy)





Bunch split and merge scheme

Present scheme:
A single pulse from the source remains a single bunch from source to collision

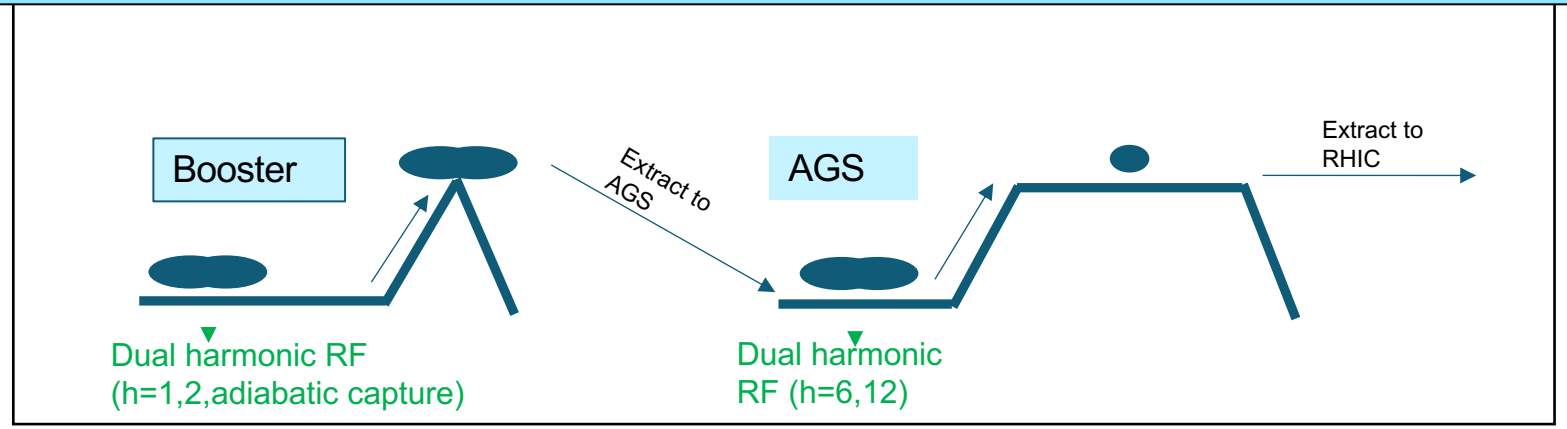
Booster and AGS injection both have defocusing RF harmonics

Add a 1->2 bunch split during acceleration in the Booster

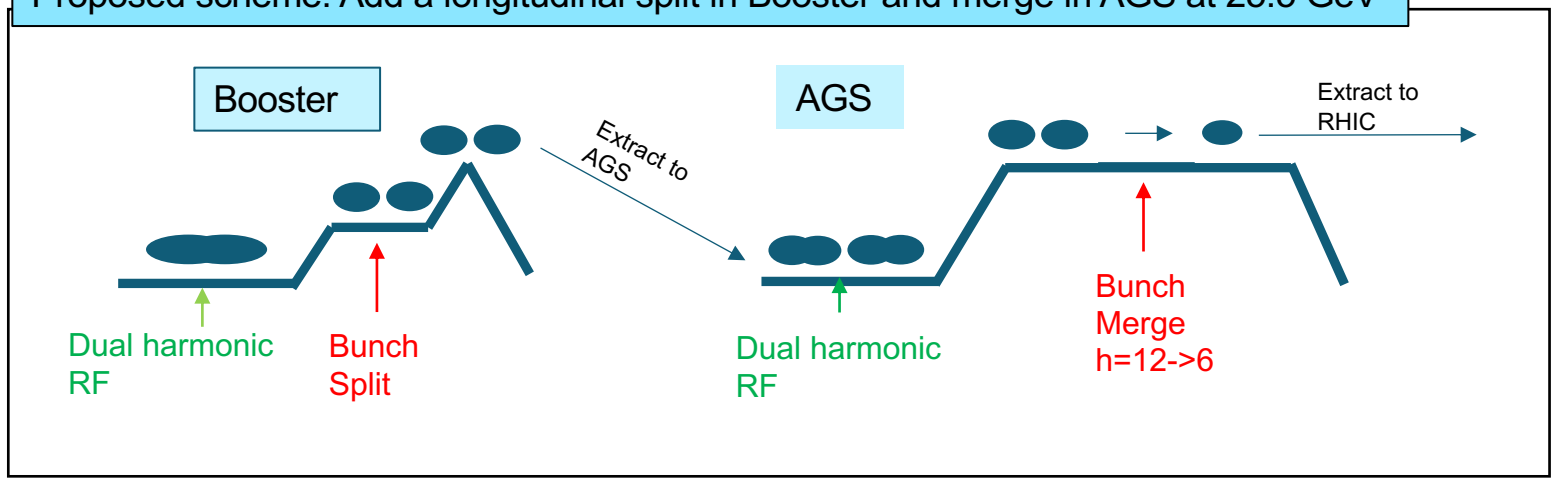
Reduces peak current at AGS injection by $\sqrt{2}$ (optimally)

Requires a 2->1 merge at AGS extraction energy of 25 GeV to recovery the per bunch intensity

Present scheme: Single bunch from source to RHIC, dual harmonic RF at Booster and AGS injection



Proposed scheme: Add a longitudinal split in Booster and merge in AGS at 25.5 GeV

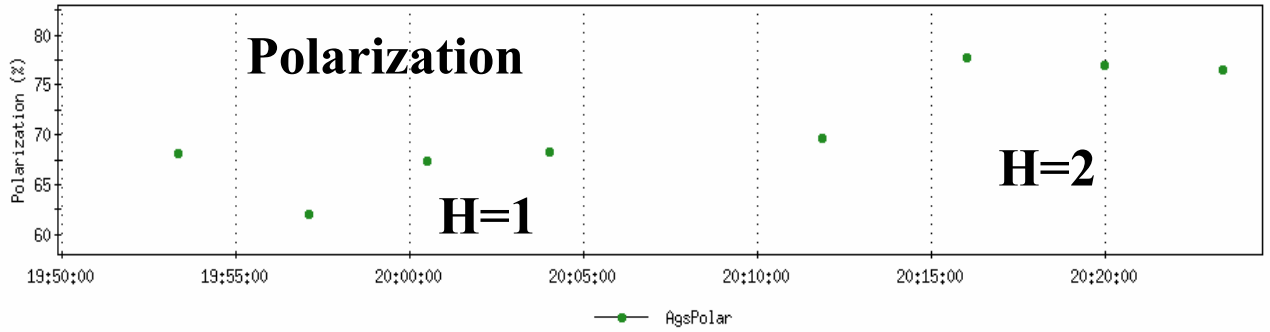


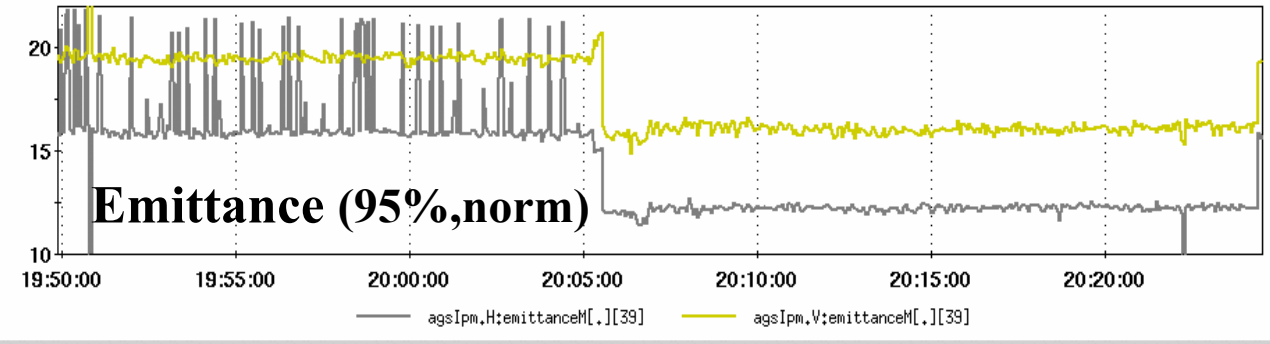
Two bunches in AGS from Run 13

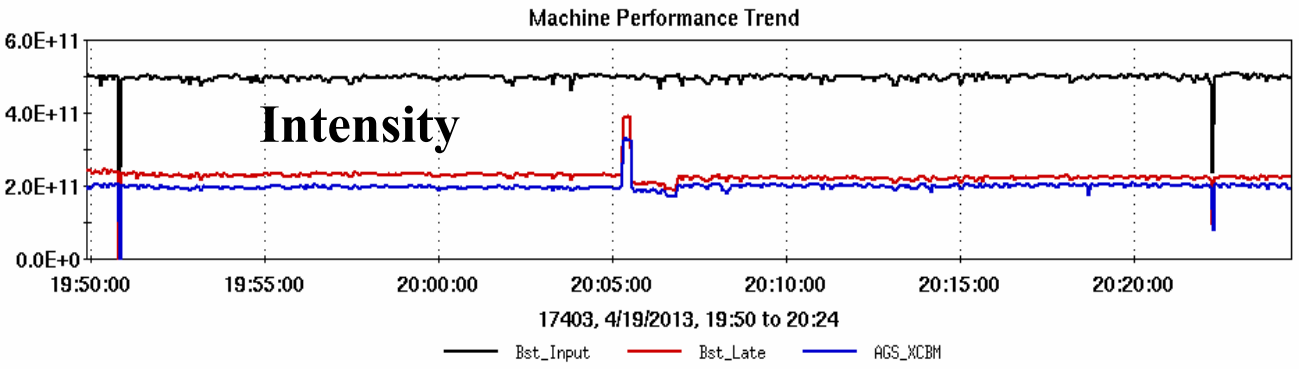
In Run 13, proton bunches were captured on h=2 at Booster injection and accelerated to AGS extraction as two bunches as a test

Improvement at the time
- 20% emittance improvement
- 12% (relative) polarization improvement

The proposed scheme splits in the Booster instead of h=2 capture to preserve dual harmonic capture (which gives lower peak currents at Booster injection)







4/19/2013	B	B_{input}	B_{late}	A_{CBM}	$MW006_H$	$MW006_V$	AGS_H	AGS_V	$P_{ave.}$
	h	10^{11}	10^{11}	10^{11}	$\pi\mu m$	$\pi\mu m$	$\pi\mu m$	$\pi\mu m$	%
19:53 - 20:04	1	5.0	2.30	2.00	10.5	3.49	16.0	19.8	66.5
20:11 - 20:23	2	5.0	2.25	2.02	11.9	3.13	12.3	16.1	75.2

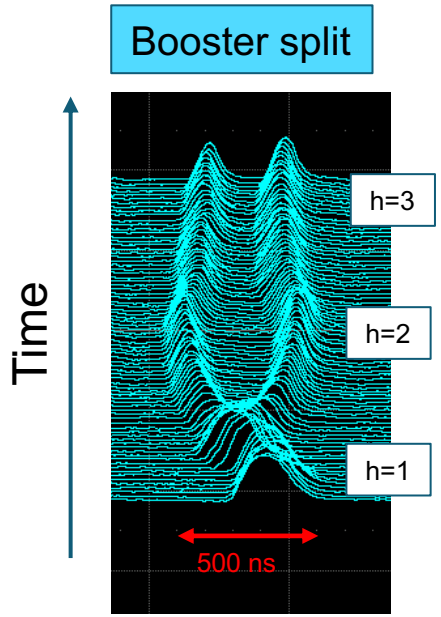
Data from H. Huang

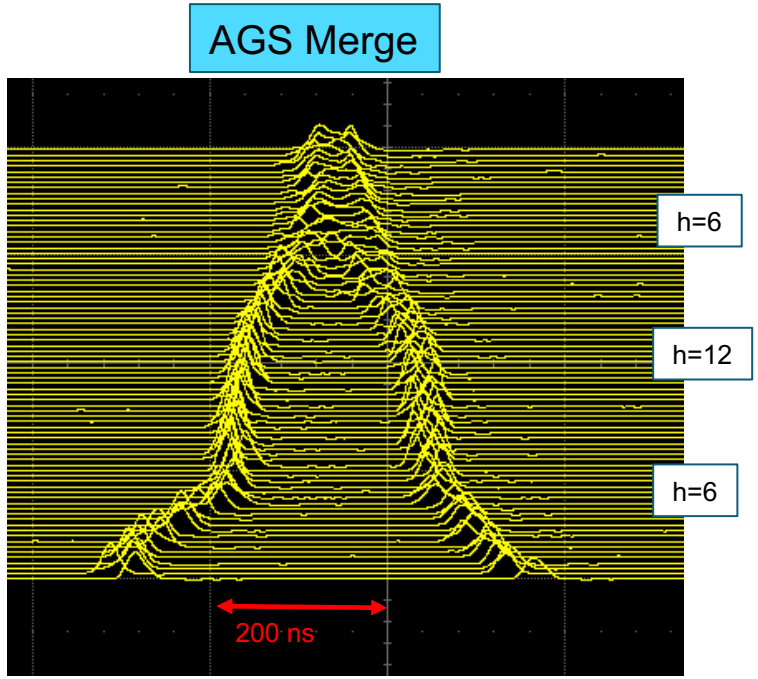
Run 21 Split/merge test

January 2021 pre-run test

- Test the longitudinal mechanics
- Basic proton setup (no snakes)
- Interleaved with two other proton efforts

- Synch period at AGS flattop is 12 ms
  - Merge takes a full second
  - Hard to maintain constant, adiabatic conditions





Booster RF:
- Capture on h=1, defocus (h=2)
- Accelerate to merge porch
- Split h=1→h=2
- 'Squeeze' h=3 to get bunch spacing for BtA transfer

AGS RF:
- Capture on h=6, defocus (h=12)
- Accelerate to flattop
- Squeeze h=6 → 12
- Merge h=12 → 6

Run 21 Split/merge test: Emittance growth

- Measured longitudinal emittance growth in the AGS
  - Factor 1.4 during acceleration
  - Factor 1.25 from merge

- Longitudinal emittance of protons not optimized in normal ops (to prevent instability in RHIC)
    - Leaves some room to recover some of the merge dilution

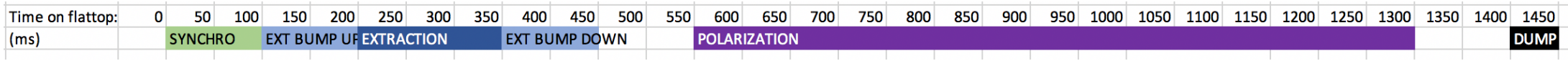
- Where does the 40% dilution during the AGS ramp come from?
  - Subject of another January proton study, still not clear

	Longitudinal Emit [eVs]		
	As measured	Run 22 plausible	
Booster extraction	0.8	0.6	Sum of 2 bunches
AGS flattop, pre-merge	1.11	0.8	Sum of 2 bunches
AGS flattop post-merge	1.38	1.0	Single bunch

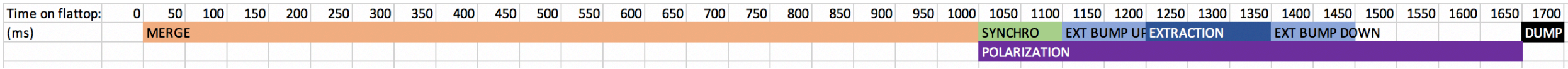
Split/merge: Operations

The 1 second merge, polarization measurement and extraction do not all fit in series on the AGS flattop

Present flattop schedule: No merge



Proposal: Merge, swap extraction and polarization measurement



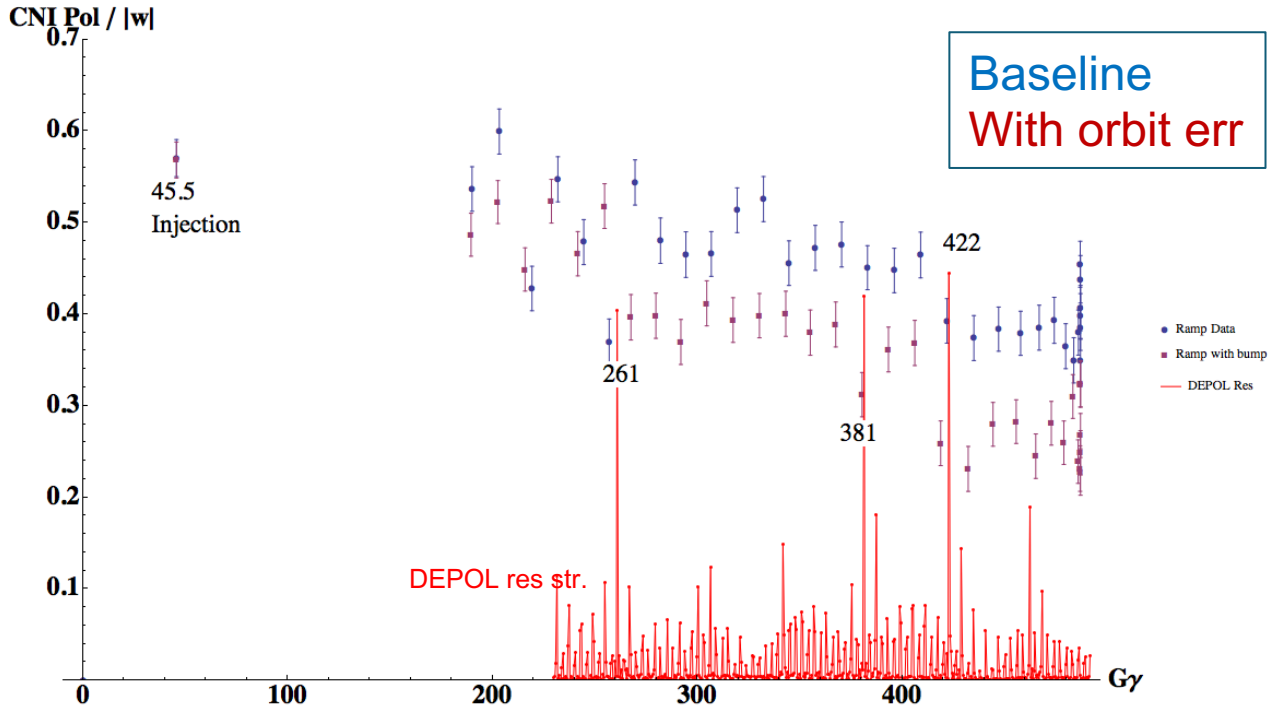
- Extend flattop by ~250 ms
- Swap ‘modes’: either extraction mode or pol measurement mode. Managed via tape.
  - Needs extra software checks in pC application.
- Disadvantages:
  - Polarization measurement has 600 ms/cycle rather than 700 ms
  - Measured beam has not gone through the extraction process.
    - Extraction on/off polarization has been measured the same many times historically
    - Checking on this in the proposed setup is harder, but possible.

RHIC Imperfections and Resonance Overlap

Run 17 APEX
- Slow ramp (~45 min!)
- Mid-ramp pC measurements
- with and without applied orbit imperfections

Lessons:
Polarization loss localized at major intrinsics (not obvious from previous full ramp speed measurements)

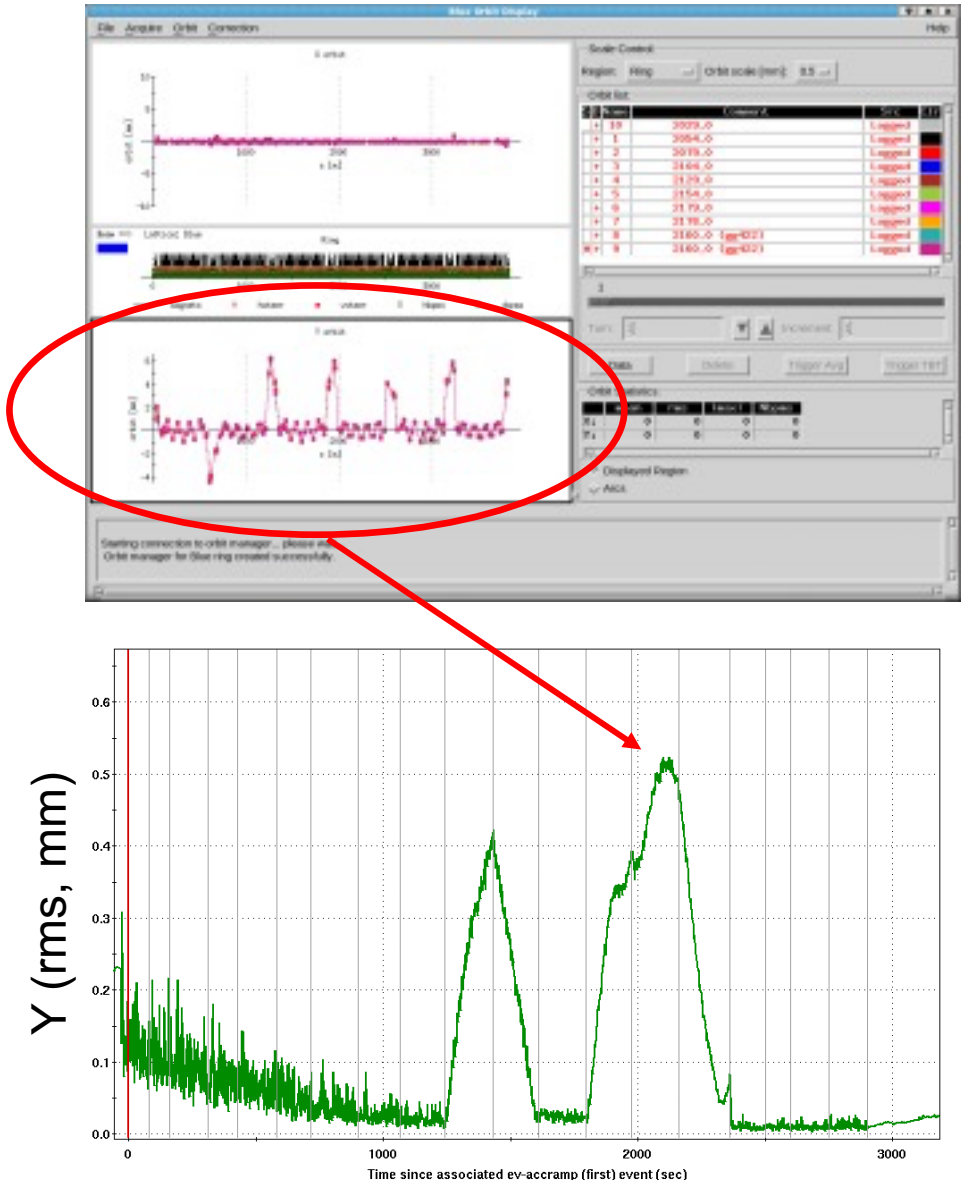
Worse with a strong overlapping imperfection



Plot from V. Ranjbar

RHIC Imperfections and Resonance Overlap

Attempts to infer absolute orbit from measurements are so far unsuccessful



Proposal:

Brute force scan of individual imperfection knobs at three strongest resonances

3 resonances x 2 phases = 6 scans
4 points per scan = 24 points (= 24 ramps, which could be physics ramps)

5 pC measurements at injection and store (each) gets +/- 3% pts uncertainty for transmission each ramp ($P_{final}/P_{initial}$)

Simulations necessary (underway) to determine optimal scan parameters to get measurable response

Spin Tilt at 255 GeV

Spin away from vertical by 12-15° at pC location at 255 GeV (Gγ = 487)

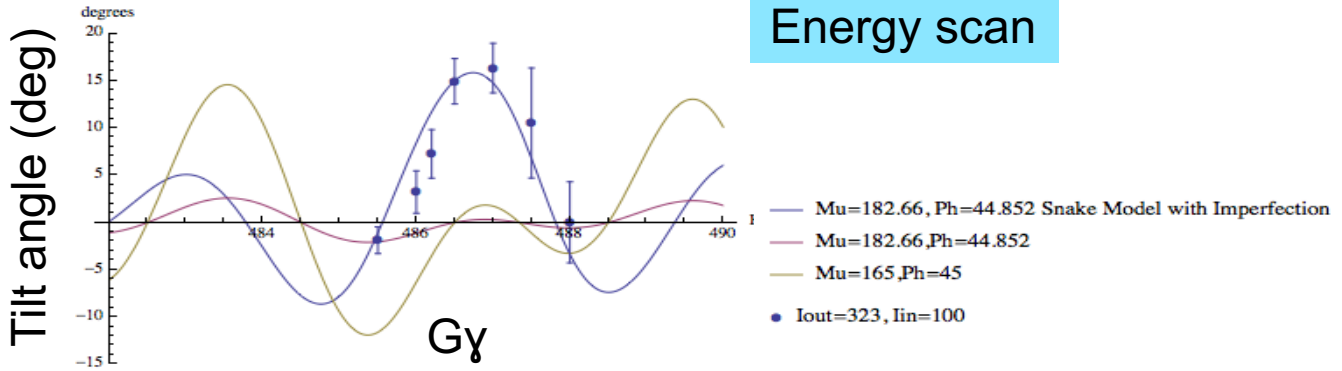
- Run 17 snake and energy scan
  - Snake detuning+large imperfection (0.2) mimics effect

There *are* snake settings that gave zero tilt at 255 GeV (locally)

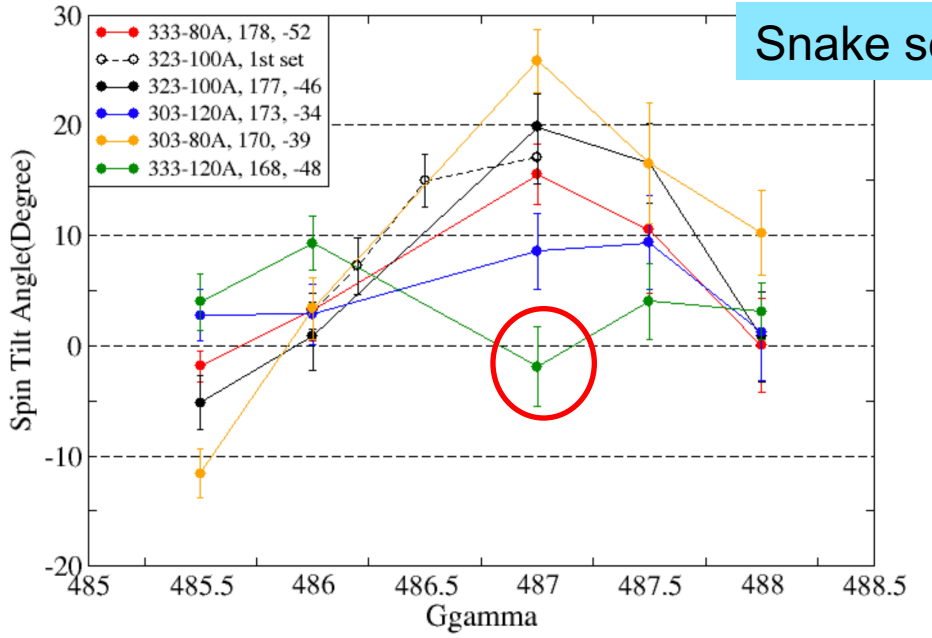
Relevant to EIC: Understanding both the actual source and corrective mechanisms (not necessarily identical tasks)

Need a plan for measurements and analysis

Energy scan



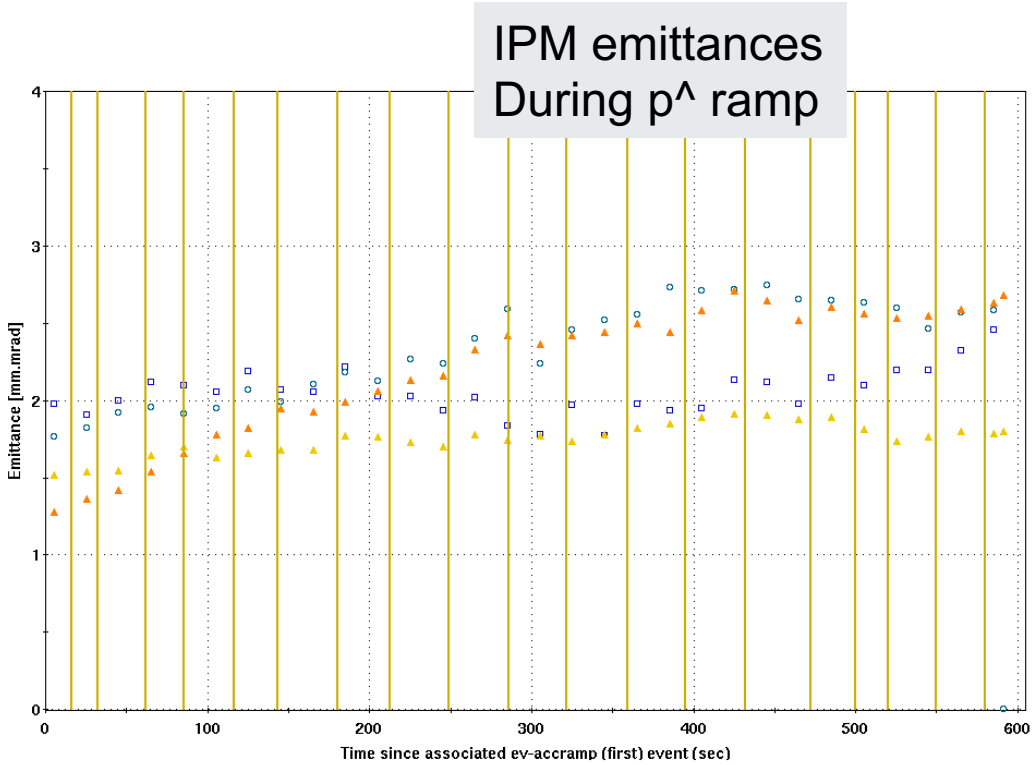
Snake scan



Measurement by Huang, Marusic, Meot, Ranjbar

Some additional avenues for improvement

- Transverse dampers
  - Used to good effect with low energy Au (originally designed for proton beam-beam instabilities with e-lens
  - Worth testing against proton emittance growth during injection and acceleration
- ‘Bunch flattening’ with 28 MHz at proton injection
  - Also used during low energy Au
  - Worth testing at injection (simple on/off testing)
  - *Operational implementation could very complicated (28 MHz cavities would need to be reconfigured for rebucketing during the ramp)*
- Higher 9 MHz voltage (+ ~30% relative to Run 17)
  - Possible small improvement in early ramp losses



Additional operating modes

- "Program time"
  - Polarized protons at 255 GeV (16 weeks)
  - CeC Au at 26.5 GeV/n (2 weeks)
    - PAC recommendation to accommodate the CeC beam request "as early as possible in Run 22 in order to allow for optimized STAR data taking"

- APEX and development
  - ^{3}He at 100 GeV/n (one ring) for polarimetry development (Run 14 configuration)
  - Au at low energy (3.85 GeV/n) for LEReC development
  - E-lens development (no additional beam mode necessary)

General setup approach:
- Single minded setup of polarized protons to the Run 17 configuration baseline store performance as soon as possible.
- Make use of the 8 hour stores to begin setting up other modes
  - (during BES-II we often set up many modes 'up front' before turning over to physics)
- Retain right to take day shifts to transition in other setups (e.g. split merge)

Beam scheduling

- 9/20 MCR Pre-injector, Booster checkout
- 9/27 NSRL Beam setup
- 10/18 Begin AGS checkout
- 10/27 AGS beam setup
- 11/1 - 11/5 RHIC Dry Run
- RHIC 4K wave Week of 11/15

- RHIC Beam following the 4K wave

Summary

- Polarized proton operation at 255 GeV with Run 17 physics requirements with possible improvements:
  - Injector split/merge to improve emittance and polarization (20% and 10% relative, respectively)
  - RHIC imperfection resonance correction for both ramp and store
- Other operating modes largely repeated RHIC configurations
- RHIC Dry Run starts November 1, announcement (with checkout tracker link) to follow soon