

RHIC Run 12
Polarized Protons
Lessons Learned

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RHIC Retreat 7/25/12

Bellport Country Club

Outline

- Overview
 - 100 GeV performance
 - 255 GeV performance
- Startup and mode change
- Longitudinal emittance
- Machine Development
- Communication and expectations

Injector Improvements

Polarization at AGS extraction higher at higher intensities than in Run 11

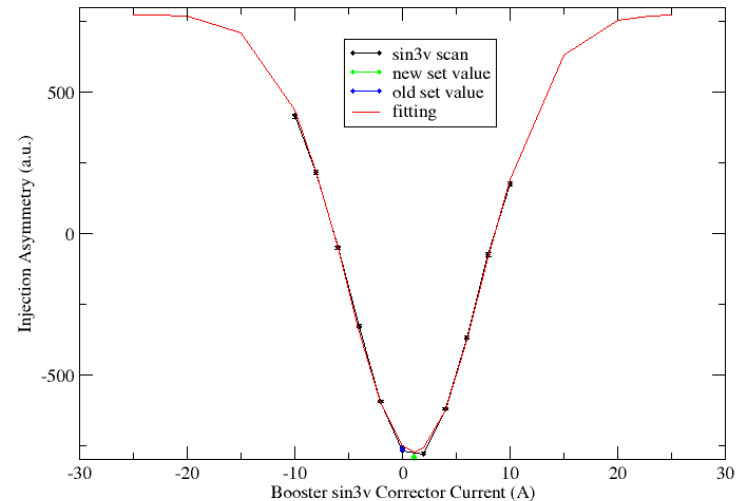
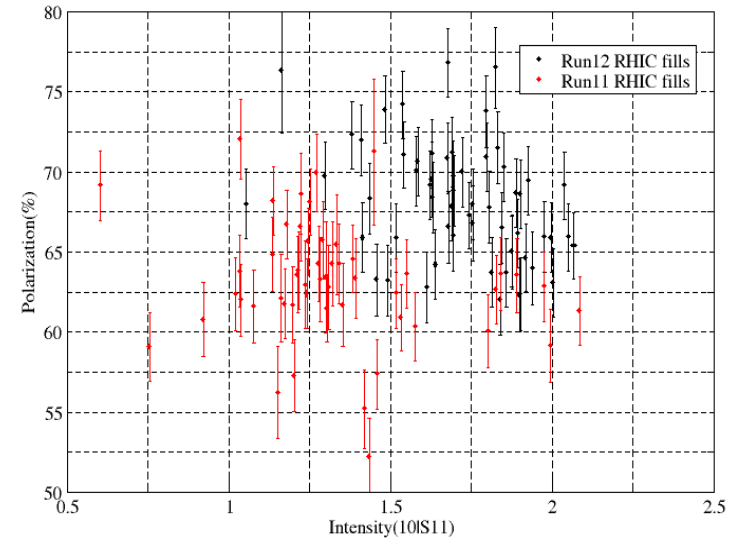
Increases from:

- AGS pC polarimeter modification allows routine measurement of spin asymmetry at AGS injection enabled optimization of Booster resonance compensation (+4% abs)

- Benefit eroded over time due to an orbit control software problem, corrected for future runs.

- Higher source intensity

- More scraping -> 10-15% smaller emittance



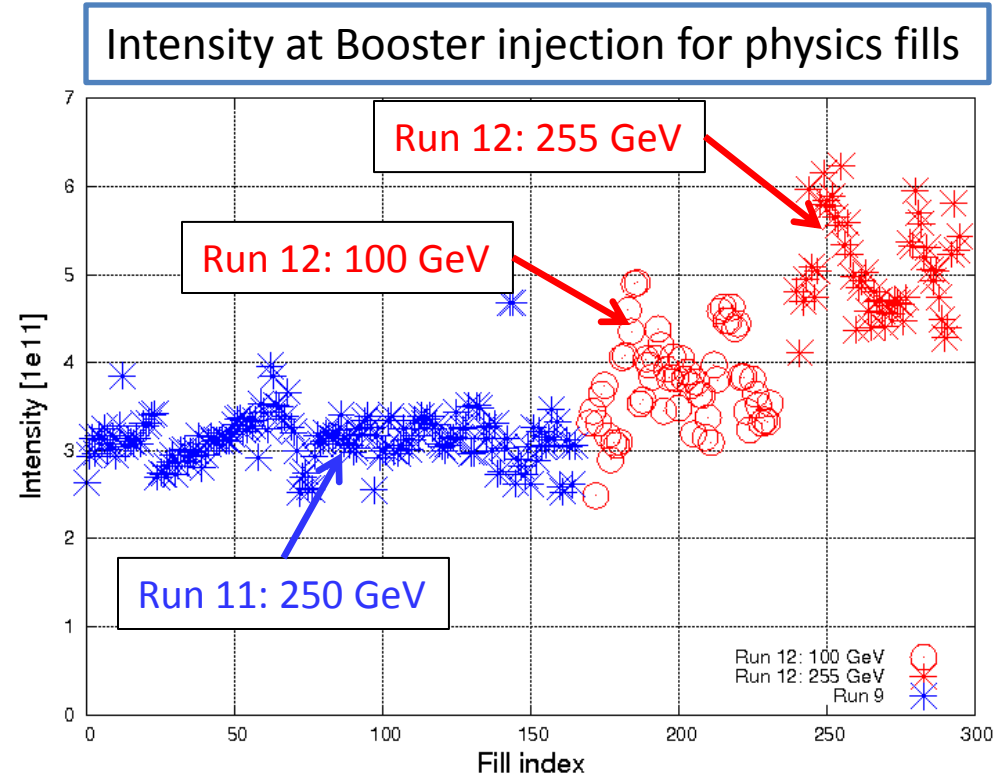
Injector Improvements: Source intensity

Source improvements yielded intensity at Booster injection as high as 6×10^{11} , nearly double Run 11 intensities

Allows additional scraping in the Booster

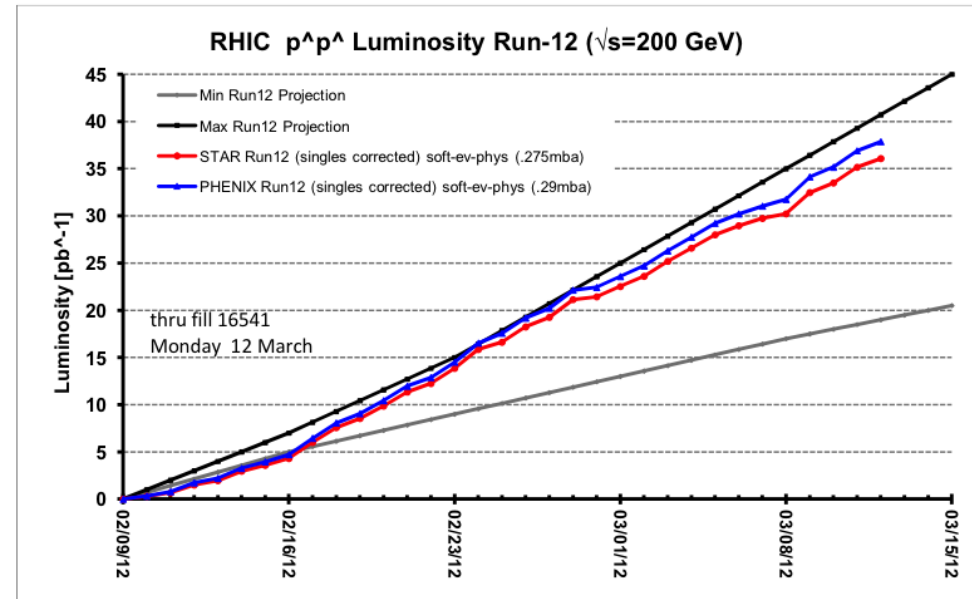
--- Longitudinal+vertical for 100 GeV

--- Vertical only for 255 GeV



RHIC Performance: 100 GeV

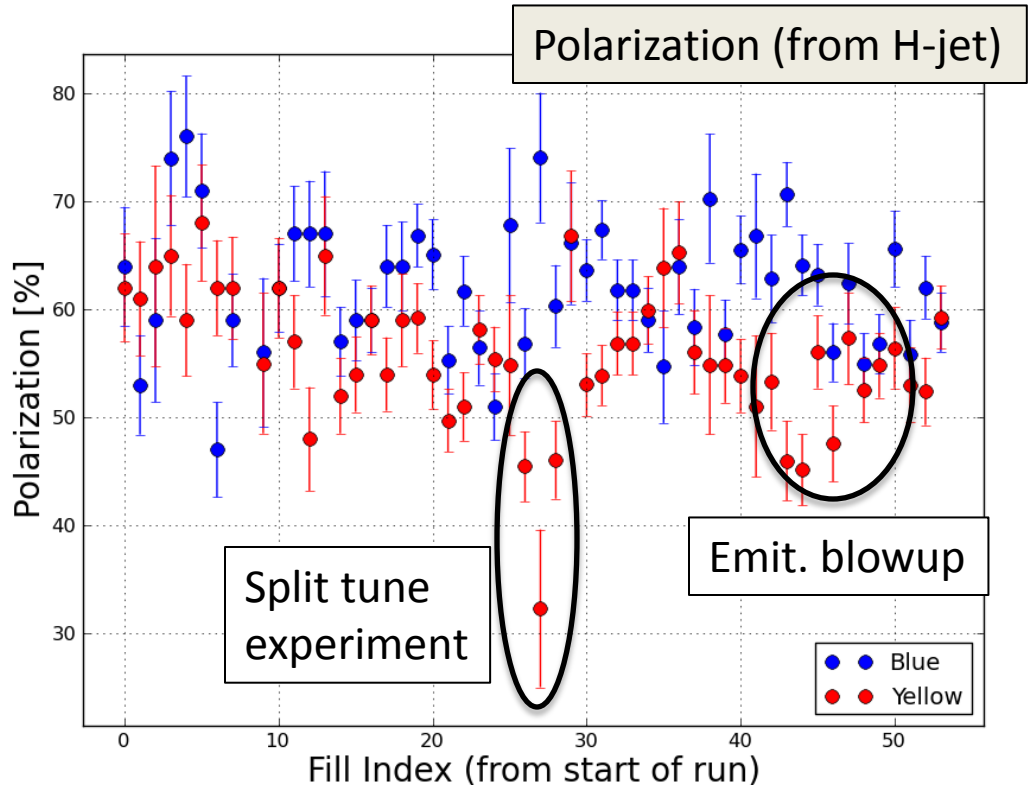
- **Luminosity**
 - Relative to Run 9
 - Increased β^* 0.7 \rightarrow 0.85 m
 - Increased intensity $1.4 \rightarrow 1.6 \times 10^{11}$ /bunch
 - Above two approximately cancel to get slightly higher peak lumi of $\sim 52 \times 10^{30} \text{ cm}^{-2} \text{ s}^{-1}$ (+5% relative to Run 11)
- **Lumi lifetime**
 - Average ~ 16 hours, compared to 7 hours in Run 9 and 12 in Run 8 (*even at 1 m β^**)
 - Run 12: First 100 GeV p⁺ run to use tune/orbit feedback for all physics stores
 - 10 Hz feedback
 - 'Blue noise' problem solved in Run 11
- Improved integrated lumi mostly due to a combination of good uptime (>60% calendar time at store) and improved lumi lifetime



Run	β^* [m]	Lumi Lifetime [h]
Run 8	1.0	12
Run 9	0.7	7
Run 12	0.85	16

Polarization: 100 GeV

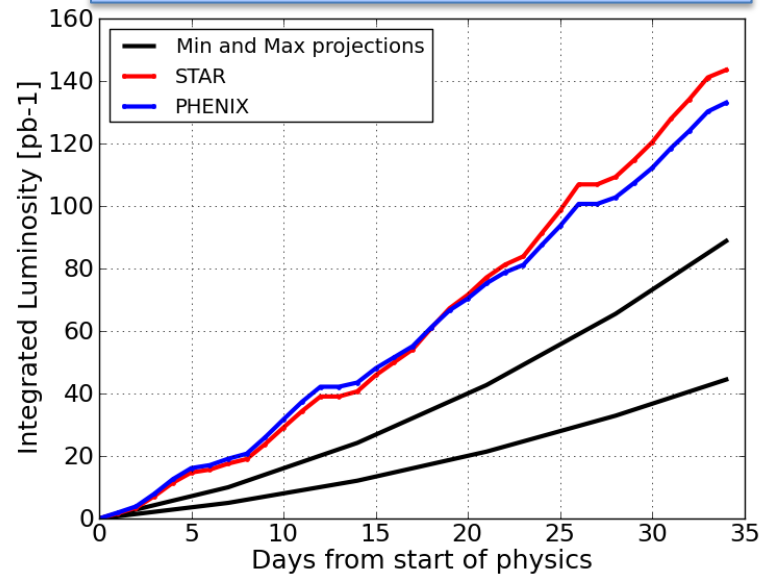
- Polarization averages
 - (B,Y) ~ (61%, 55%)
 - Yellow slightly higher (57%) when omitting 'split tune' fills and the emittance blowup period
- Polarization decay at store varies over the run, but is typically 0.5%/hr in blue and 1%/hr in yellow (absolute)
- Standard store length is 8 hours



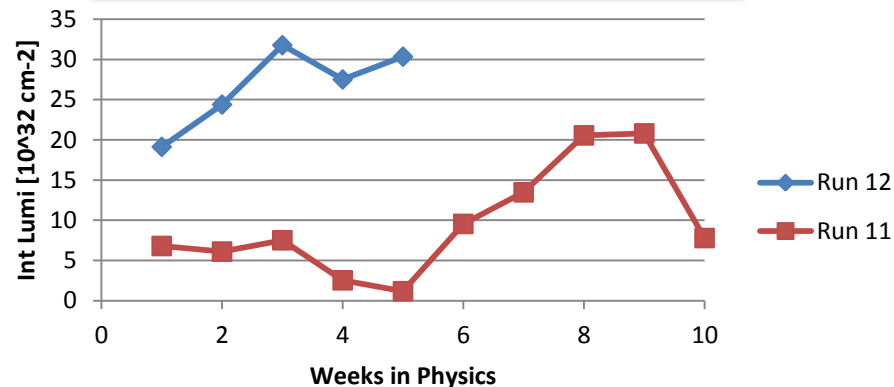
RHIC Performance: 255 GeV

- Luminosity
 - Peak
 - ~25% higher than Run 11
 - Smaller emittance
 - Source intensity + scraping
 - Less growth in AGS
 - Integrated
 - Same in first week of Run 12 as best weeks (8,9) of Run 11
 - 9 MHz RF commissioned in Run 11, operational day 1 in Run 12
 - No 'big' (multi-day) failures
 - Changeover from 100 GeV, 3.5 days, (with maintenance)
 - Enabled largely by tune/orbit feedback
 - tape/config control

Integrated Luminosity: 255 GeV

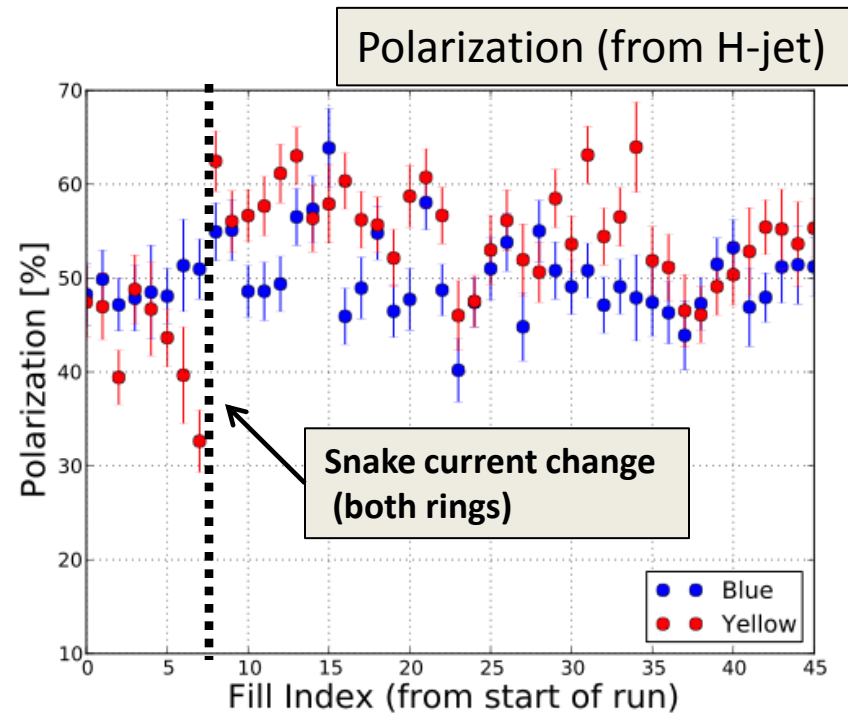


Integrated Luminosity by Week



RHIC Polarization: 255 GeV

- Run 11 48% +/- 0.5 (Jet, both rings)
- Run 12 Blue 50%, Yellow 55% (each +/- 0.5)
- Adjusted snake current during ramp between 100 and 255 GeV
 - Yellow +5% (abs)
 - Blue: Ramp efficiency may have improved (not clear from jet alone)
- Further (large) scans of snake currents show polarization is largely insensitive to changes around this configuration
- No obvious improvement in polarization decay from increasing energy to 255 GeV
 - 0.7%/hr, consistent with Run 11



The Run Coordinator Delegates.

Detailed polarization analysis:

Mei and Haixin this afternoon

Polarimeter status (and noise remediation):

Bill Schmidke, also this afternoon



Startups and Mode Changes

- Peak performance was essentially the same as the projections
 - Primary discrepancy was how fast we got to peak performance
- 1. There is no need for a one week 'ramp-up' (two shifts for experiments, one for development). Get to previous peak, go to three shifts physics, incrementally improve from there. Retain day shift for contingency.
 - If necessary, maybe have short stores for the first week.
 - 6 bunches = 56 bunches
 - 56 bunches + chrom adjustment + ramp collimation = 109 bunches
- 2. Written startup plans are key (especially for commissioning)
 1. Don is 150 pages worth of lucky
 2. RF spelled out LL commissioning plan really nicely.
- 3. Beam work goes really quickly (faster than p.s., RF setup)
 1. During initial startup, plan ahead for MD/APEX style activities at injection.
- 4. 'Day trips' like large working point changes, beta* changes should be treated like mode changes.

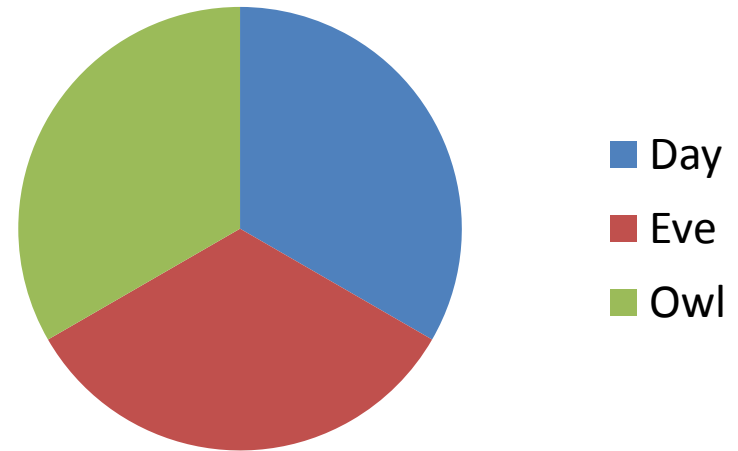
Problems with Startups and Mode Changes

They are too fast!

Groups that previously had multiple shifts between call-ins now do not

- Capture, first ramp and rebucketing come together within one shift of each other
- Instrum setup for injection and ready for ramp are essentially the same thing.
- Scheduling difficulties:
 - RF->Instrumentation/FB take alternating shifts
 - But then everyone needs to be around together for first ramp
 - No group can split into shifts

Breakdown of One Earth Day by Shift



Results the same even in the frequency domain

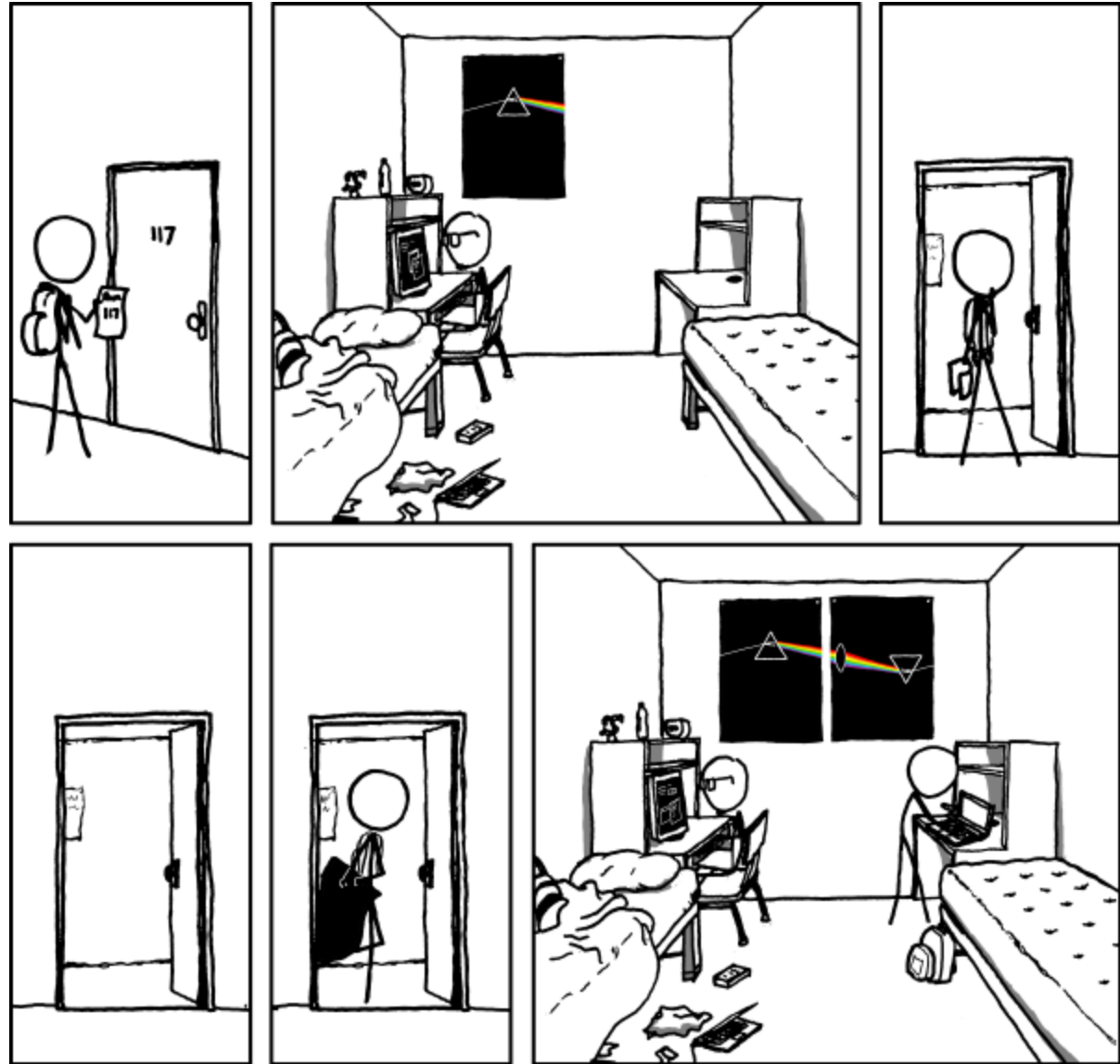
Planetary upgrade outside DOE long-range planning scope

Problems with Startups and Mode Changes

Requires reliable chrom
measurements:

Some indication that the
'wiggles' method was not
accurate

Should fix that and
develop the 'offset' ramp
method

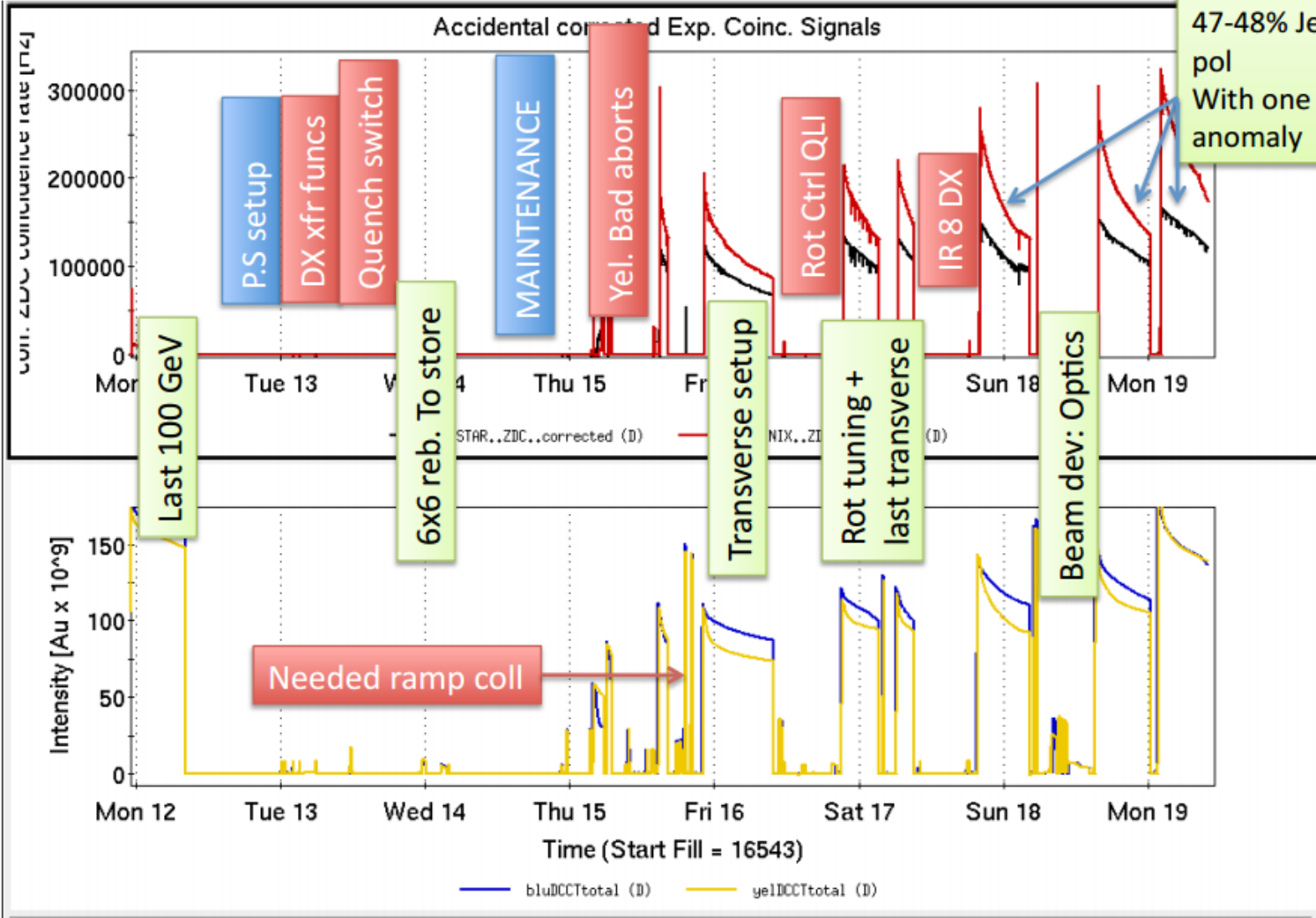


Polarized Proton: 100 GeV to 250 GeV Changeover Schedule (Run 12)

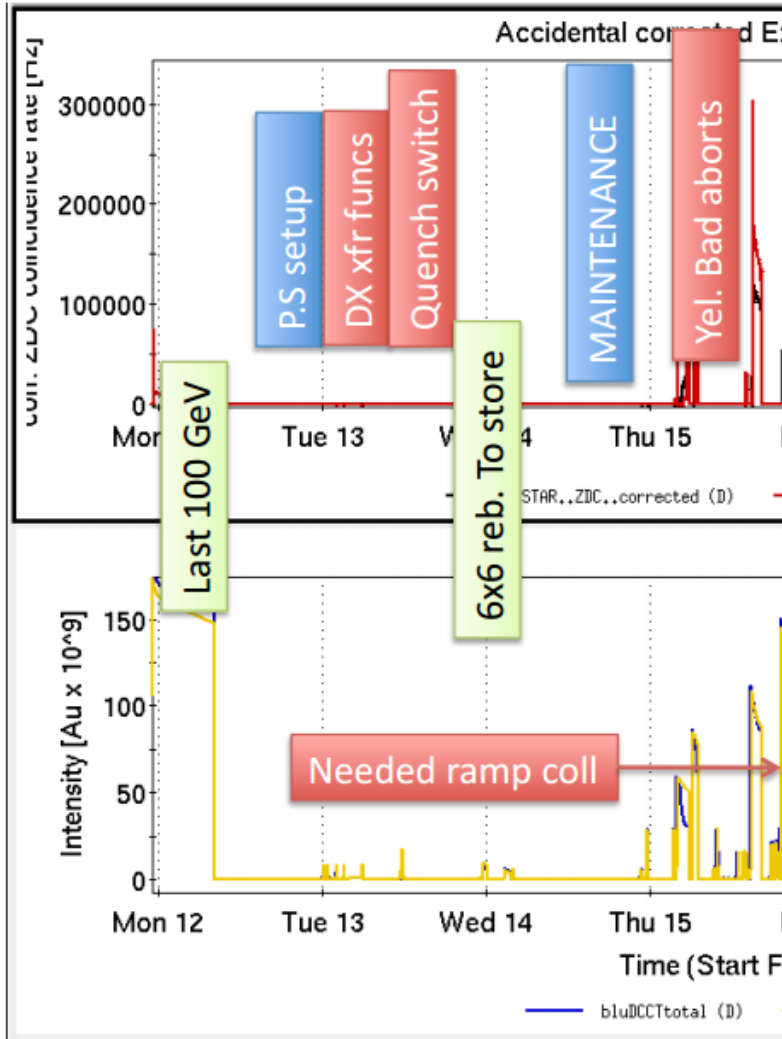
	12-Mar	13-Mar	14-Mar	15-Mar	16-Mar	17-Mar	18-Mar
	Mon	Tues	Wed	Thur	Fri	Sat	Sun
OWL	100 GeV Physics	Energy ramp increasing bunch number/intensity	Ramp dev. OR, potentially one transverse store	Ramp dev., Long. Store conditions	250 GeV physics		
DAY	p.s. setup 2-3 hours, 250 GeV Ramp Development	Rebucketing setup	MAINT.	Finish standard optics measurements, transition to long. Stores	Contingency		
EVE	Energy ramp development	Rotator ramp dev.	MAINT.+ Recovery and ramp devel.	Transition to 250 GeV physics	250 GeV physics		

Polarized Protons: 100 to 255 GeV

Longitudinal Stores:
47-48% Jet pol
With one anomaly



Polarized Protons: 10



Deviations from expectation:

Power supply setup +1 shift
 Wfg problem with 255 GeV, +2 shifts
 No ramp collimation, +1 shift

Rebucketing, -1 shift [Yeah!]
 Rotator ramp, -1 shift [Yeah!]

I think 2 days is about the theoretical minimum.

3.5-4.5 days is at reasonable estimate, with contingency.

Let's try to avoid maintenance during setup.

By Friday night, we had 109, 1.6×10^{11}

Are these fast mode changes reproducible?

Yes.

The Run Coordinator Delegates Some More.

Keeping Startups Awesome: Greg's talk tomorrow.



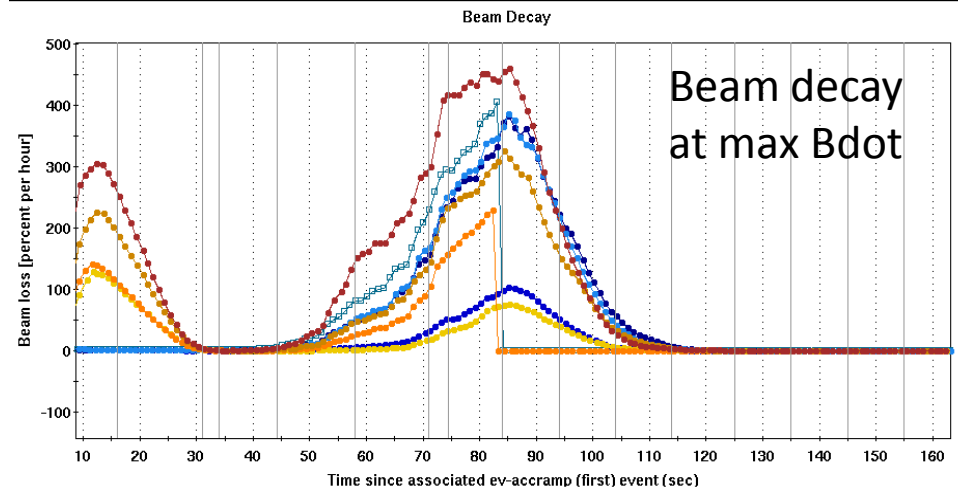
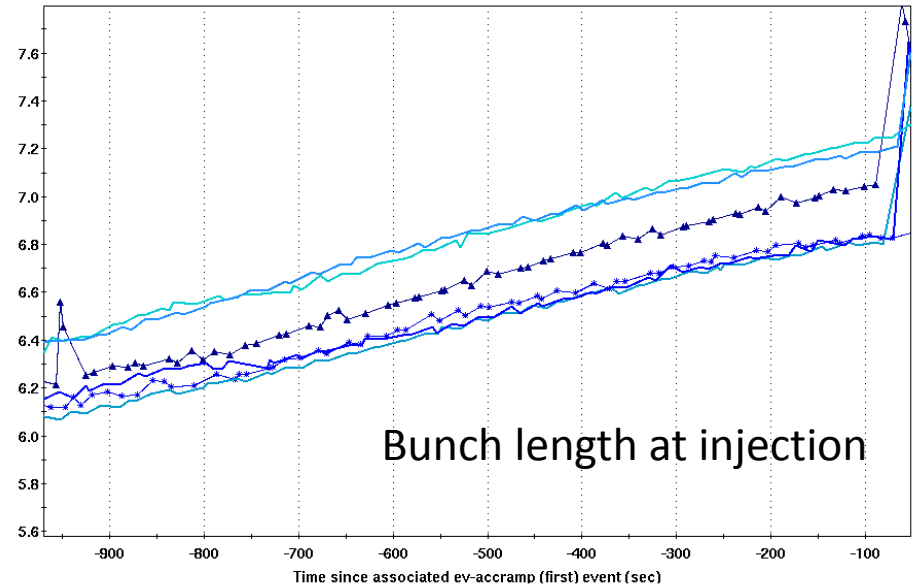
Longitudinal Emittance

Longitudinal emittance limits the luminosity for 100 and 255 GeV:

- 100 GeV
 - Rebucketing
 - Vertex cut $\sim 16\%$, want 20%
- 255 GeV
 - Vertex OK
 - Limited to $1.8e11$ by ramp, would like $2e11$ (+20% LUMI)

Nearly ALL the MD during the polarized proton run and TWO TALKS (tomorrow afternoon) dedicated to this effort

[I will defer to those talks for full analysis]



Machine Development

'Fallout' is downtime attributable to the development or unexplained

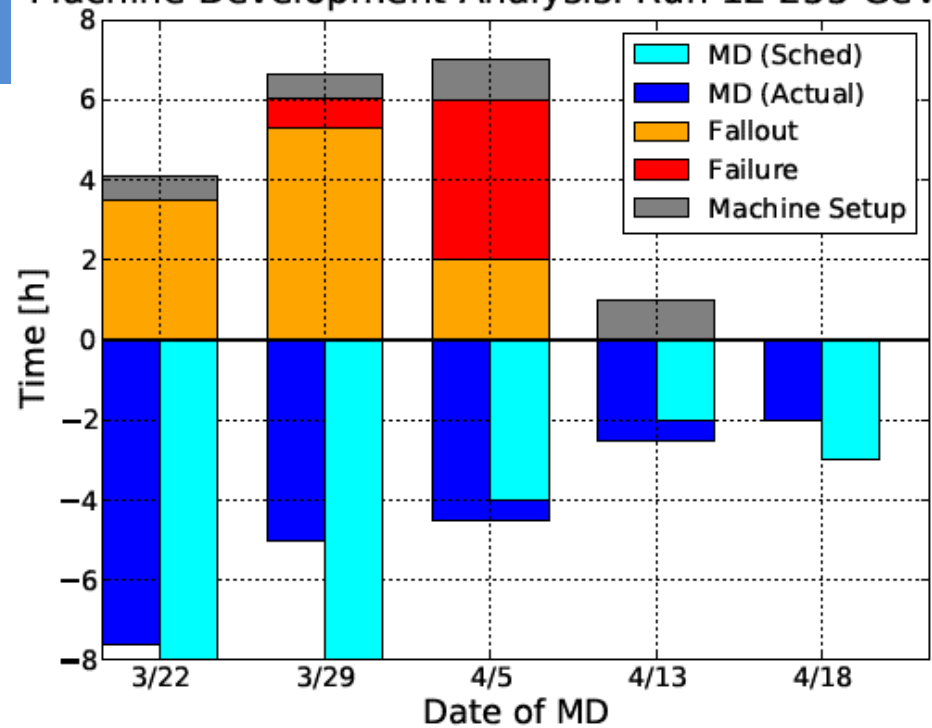
'Failure' is downtime independent of the MD effort, but which delayed return to physics

'Machine Setup' is time after MD ends that is reasonably used to get back to physics

Almost all MD took place during 255 GeV

Almost entirely to improve longitudinal emittance (2-3 hrs optics/coupling)

Machine Development Analysis: Run 12 255 GeV p⁺



Mode	Total [h]	
MD (Sched)	25	
MD (Actual)	21	~2 stores
Fallout	10.5	~ 1 store

There were ~60 255 GeV stores total.

Machine Development

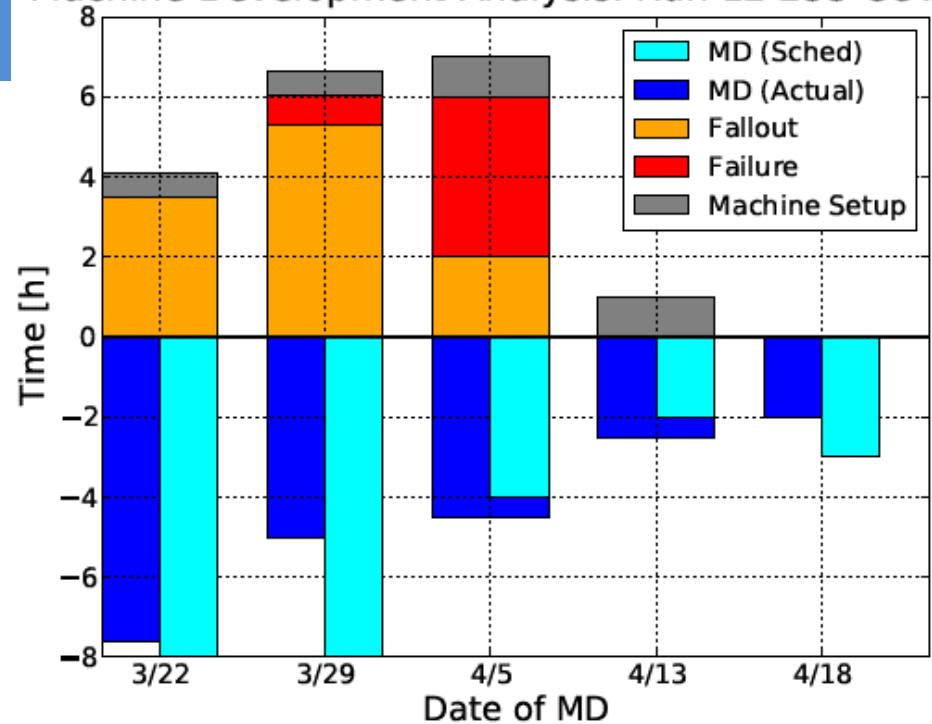
In all three instances, the **Fallout** is yellow injection:

- 3/22: Booster scraping scheme changed, fast injection loss
- 3/29: Yellow injection lifetime
- 4/5: Devices not returned to nominal + injection instability

Injection instability/lifetime problems happened throughout the run

- Chrom control really important at this intensity
- Most efficient remediation is to measure the chroms and set appropriately
- One minute measurement saves many lost fills (instability at end of fill)

Machine Development Analysis: Run 12 255 GeV p⁺



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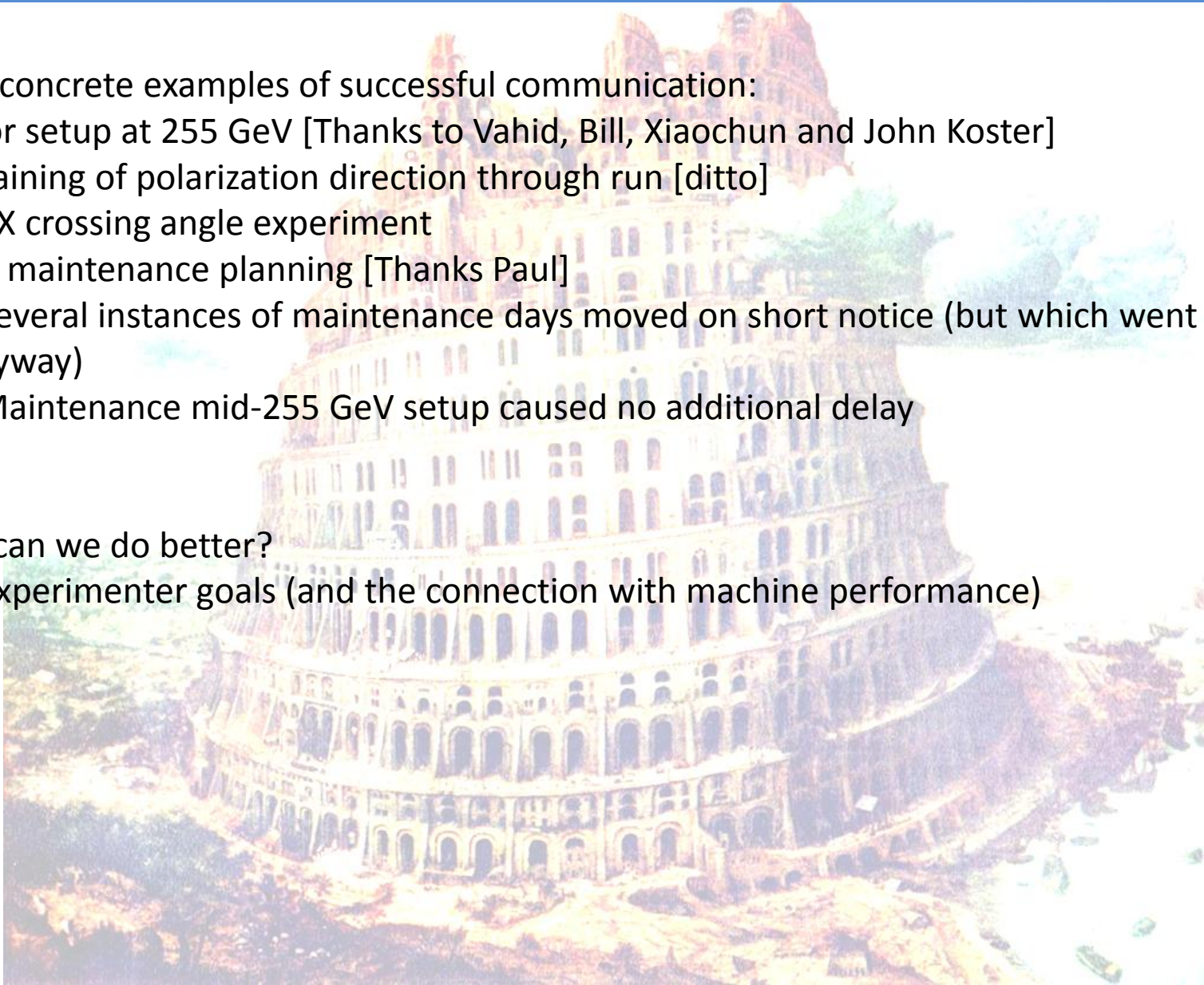
Communication

Several concrete examples of successful communication:

- Rotator setup at 255 GeV [Thanks to Vahid, Bill, Xiaochun and John Koster]
- Maintaining of polarization direction through run [ditto]
- PHENIX crossing angle experiment
- Stellar maintenance planning [Thanks Paul]
 - Several instances of maintenance days moved on short notice (but which went well anyway)
 - Maintenance mid-255 GeV setup caused no additional delay

Where can we do better?

- Experimenter goals (and the connection with machine performance)



Patterns in the Luminosity

What is the 'sawtooth' in the sampled lumi?

Does not show in delivered.

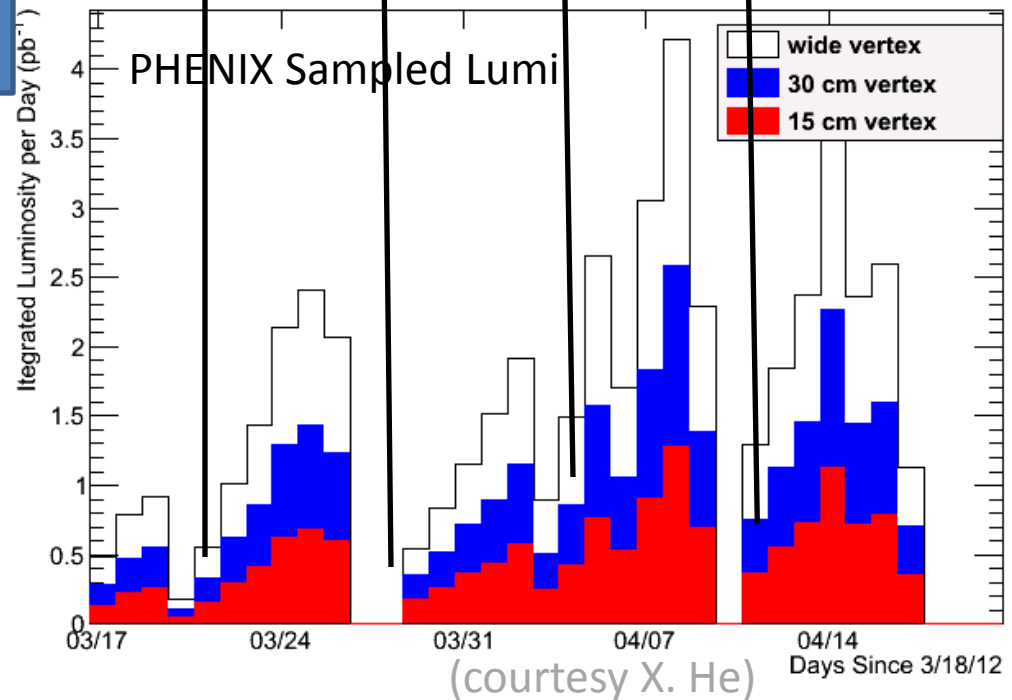
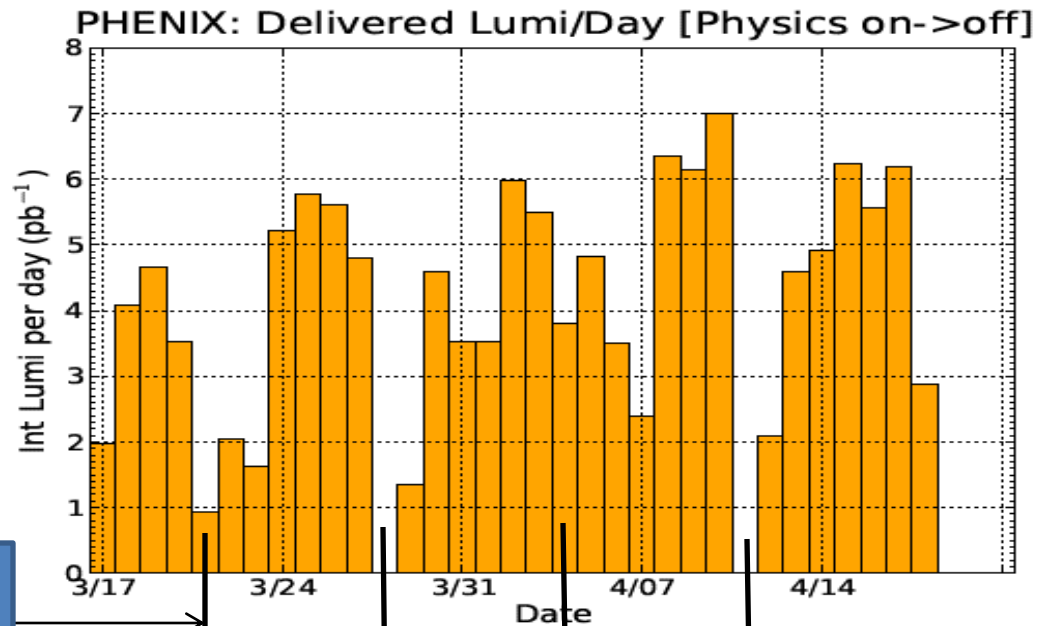
Where does the lumi go?

It's *NOT* the vertex

Two caveats:

- 1) Delivered lumi not consistently handled for stores that span midnight (~1 pb⁻¹ could slip a day in either direction)
- 2) Either the dates in the PHENIX plot are shifted early one day, or Tuesdays are worse than Wednesdays.

Connects Wed's

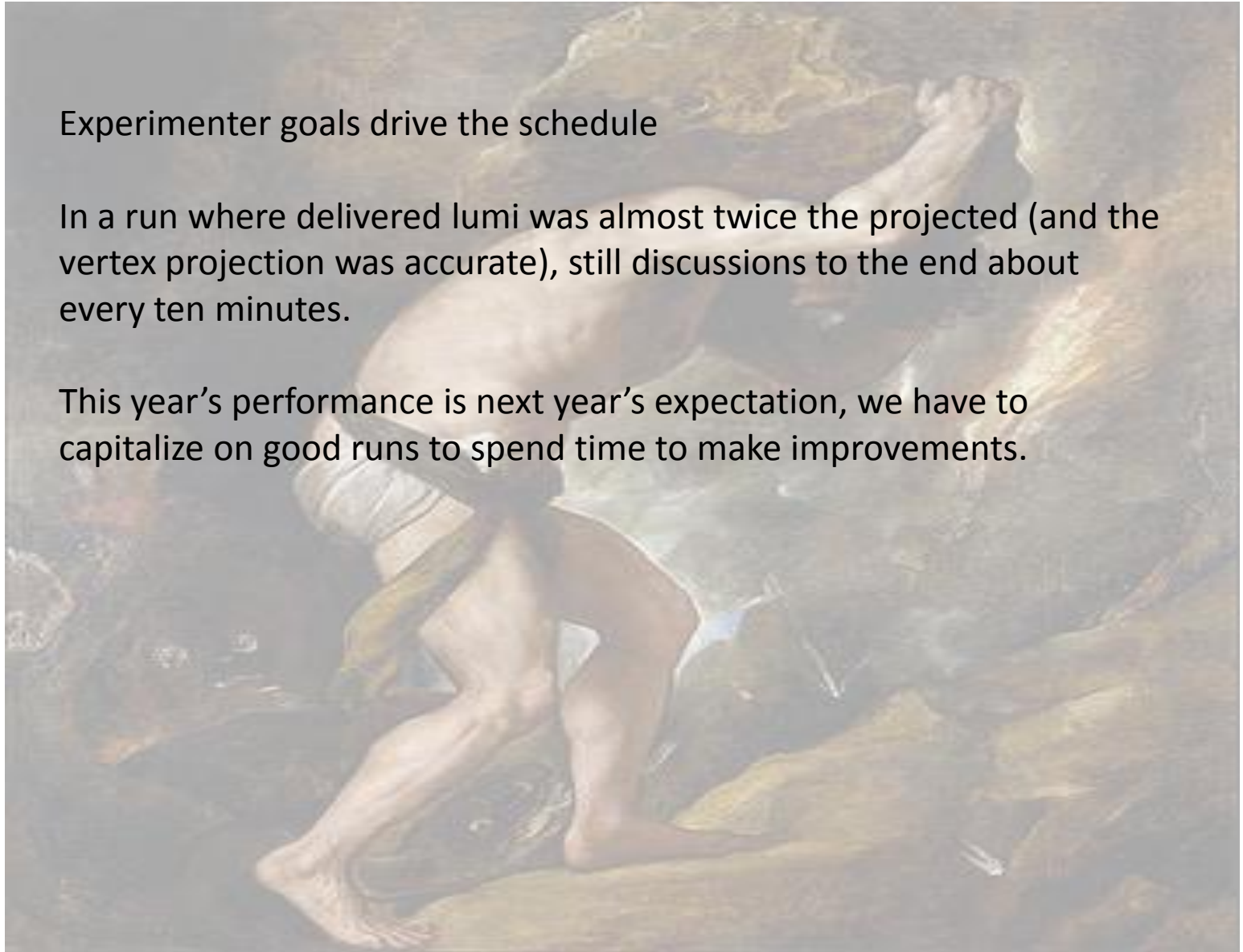


Why is this important?

Experimenter goals drive the schedule

In a run where delivered lumi was almost twice the projected (and the vertex projection was accurate), still discussions to the end about every ten minutes.

This year's performance is next year's expectation, we have to capitalize on good runs to spend time to make improvements.



Summary

Run 12 was a great success!

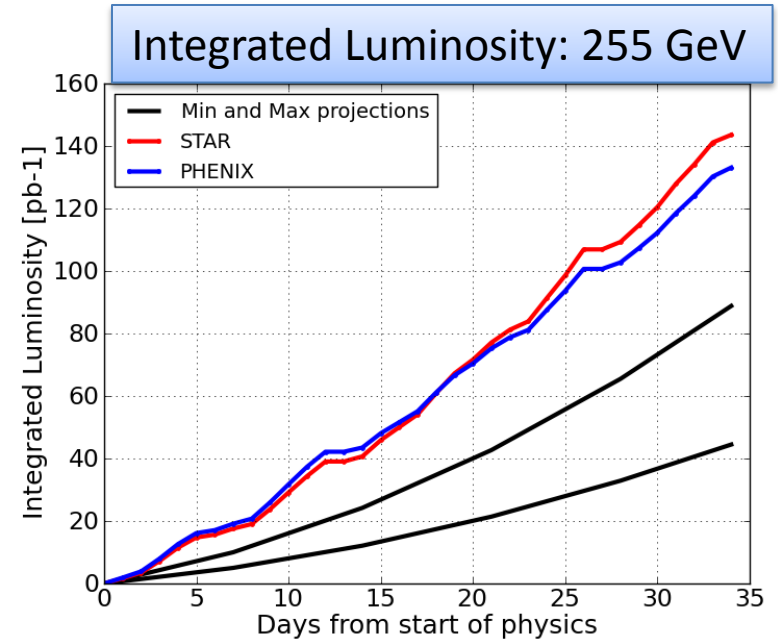
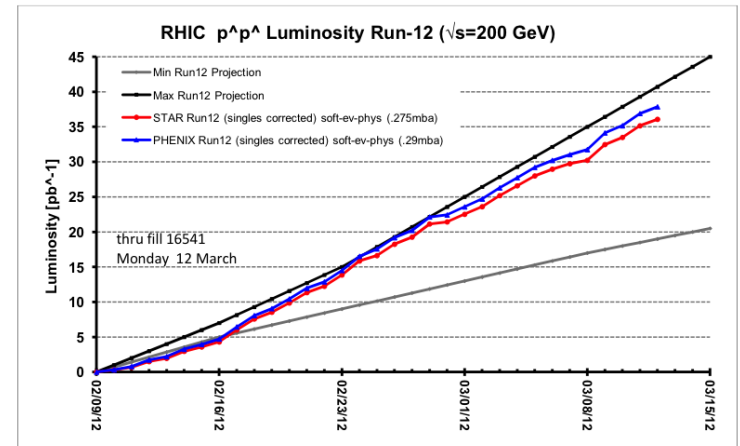
Records in lumi, polarization (and energy!)

Product of many years of work in many areas:

- Spin physics
- Instrumentation and feedback
- RF
- Power supplies
- Operations and maintenance

Very well positioned to integrate planned upgrades

- E-lens
- OPPIS Source upgrade



THANK YOU!



Dance in a Madhouse – George Bellows