sPHENIX backgrounds

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2024 RHIC Retreat
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MVTX backgrounds in Run24, summary

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- Identifying the source of backgrounds
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Summary

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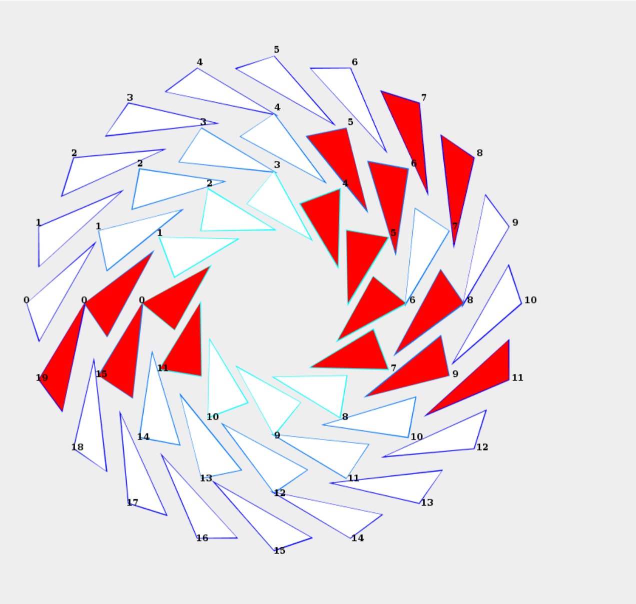
The MVTX Detector Background Issue

The MVTX is at the center of the sPHENIX detector.

- It was designed to operate in full-streaming mode, i.e. the system is in constant readout.
- 48 staves in three layers, centered at the IP, extending to ± 13.5 cm. More on the geometry on the next few slides.
- If any of the staves are overloaded with charge, the entire stave will go into auto-recovery, a 20 s reboot process to reset/re-initialize that system$\Rightarrow$no data read out during auto-recovery.
- Primary source is yellow beam. Blue beam had significantly lower rates (56 bunches in blue had lower rates than one single yellow bunch).
- Details seen in John Haggerty, sPHENIX Summary and the Run25 Plan

The MVTX detector



- MVTX auto-recovery display shown on left where red corresponds to staves in auto-recovery.
- Simulations by sPHENIX show a single Au ion (or shower from striking the beampipe) with a longitudinal trajectory, striking the MVTX would result in single/multiple MVTX staves going into auto-recovery
- Auto recovery process is 20s

MVTX geometry

Beampipe radius	2.14 cm
MVTX Layer 0	2.4 cm
Layer 1	3.1 cm
Layer 2	3.9 cm

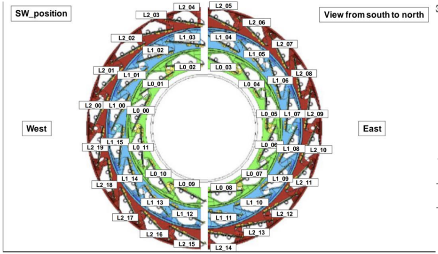
wafer thickness is 50 μm

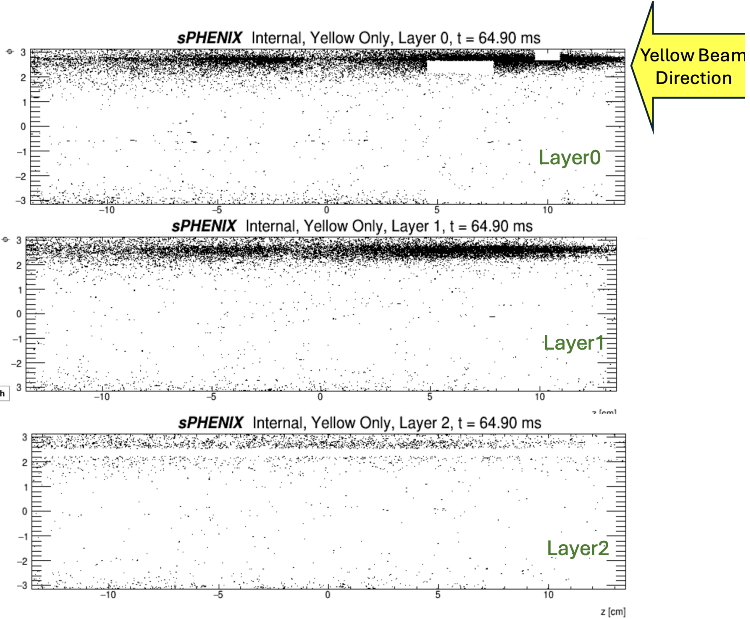
MVTX Backgrounds

No problems in proton-proton

Major background in Au+Au, even with just one bunch in the yellow ring (i.e., no collisions)

Beam backgrounds… induces auto-recoveries in MVTX



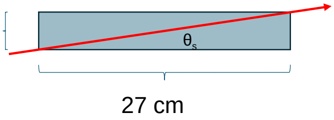


From C. Dean

RHIC/MVTX Local Geometry

MVTX spans +/-13.5 cm around IP
Active layer is 50 um

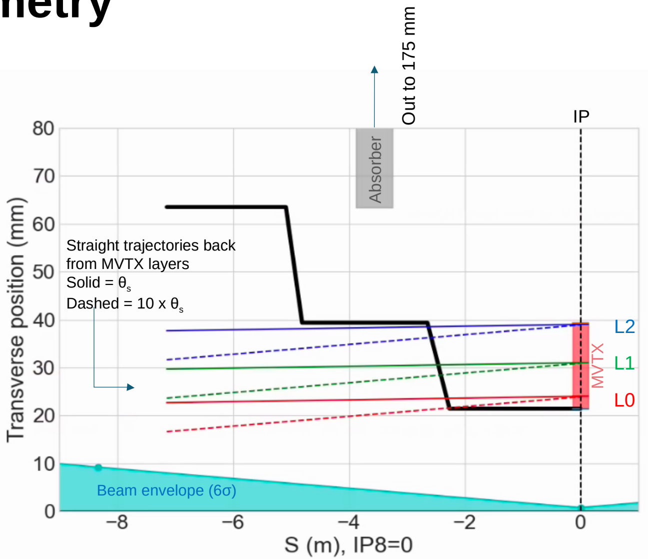
θ_s: "Skimming" angle: max angle of a trajectory that traverses the whole length of one MVTX layer: 50um/26.5cm = 0.19 mrad



Beam envelope = 6σ, no dispersion, ε=2.5 um rms,norm
No dispersion included, no crossing, nominal beam pipe

Whatever exits the pipe (doesn't need to be beam Au necessarily), probably exits at the small taper
Geometry does not exclude the larger taper, but would traverse L2->L0

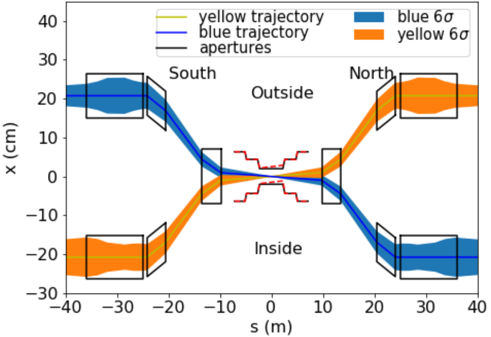
Possible to load the medium pipe with absorber discs? (not *today*, obviously)

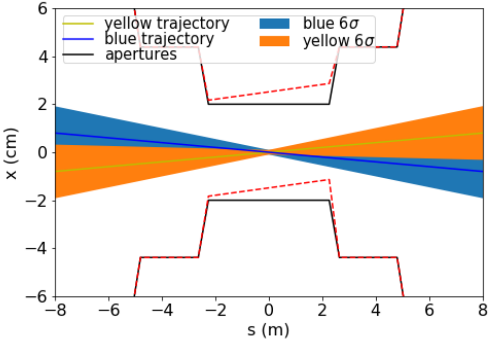


From V. Schoefer

Aperture analysis with misaligned beampipe

End of store without cooling, ϵ=4 um





Notes:

- Extreme case.
- Start of store is half the size and with cooling, there’s at least another factor of two.
- Only in this extreme case are we close to scraping in the triplets/DX entrance.

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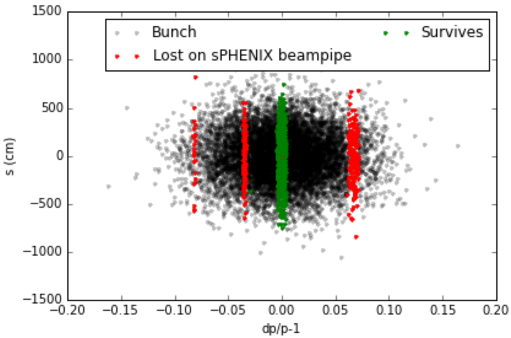
Passing large bunch from DH20 through IP



A very oversized bunch was generated and tracked through the IP

- Triplet, DX, D0, and sPHENIX apertures put into model. This did not include apertures in the arcs.
- Particles with specific momentum values are lost at the sPHENIX beampipe (red). Must be generated through reactions/capture somewhere.
- Used to inform source of losses. Needs more in depth tracking studies to determine possible origin.

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Timeline of MVTX diagnostics

- 10/7, physics running (delayed approximately 5 days due to pulsed power issues)
- 10/9, sPHENIX has 56x56, reports bad background status, found auto-recovery not enabled. Decision made to install absorber on 10/10.
- 10/10, absorber installed. sPHENIX auto-recovery signal sent to controls bad, fixed 10/11.
- 10/11, no change to sPHENIX backgrounds with absorber installed, reported no change with reduced bunch numbers from 56 to 12. MD to study their backgrounds scheduled. Meeting to discuss backgrounds at 1300. Controls produce MVTX display (Thank you to John, Seth and Wenge).
- 10/12-10/14, studies continue with a single beam (sometimes one in each ring) to diagnose issues.
- 10/15-10/21, studies with 12+ bunches in one/both rings.
- 10/11&10/14&10/18, meetings to review status of current studies.

sPHENIX MVTX Backgrounds studies

Studies performed and their implications

Study	Summary
Yellow only studies	High backgrounds even with single bunch → prompted single yellow bunch studies
Blue only studies	Significantly lower backgrounds than with yellow, 56 bunches in blue better than single yellow bunch → primarily sourced by yellow
Unrebucketed beam	Improved auto-recoveries → affected by bucket area
Local steering (position and angle)	Significant reduction in auto-recovery rate → losses can be moved locally and redistributed
Unsqueeze of IP8	No significant change → losses not the result of local scraping in triplet or local dispersion
Squeeze of IP10	weak change in auto-recoveries with a bump at IP10 → particles can be lost at upstream squeezed IR
Adjustment of global octupoles	Little to no effect → not from high betatron amplitude particle
Prefire protection bump	Significant reduction when combined with local steering and 12 bunches (did not scale to 56 bunches)→ off-momentum particle
Bump scan in dispersive region	reduction in auto-recoveries → phase of prefire protection bump may not be optimal & bumps far upstream affect backgrounds

Prefire Protection bump with local steering

The best results were from the prefire protection bump and local orbit steering, summarized in table below.

	Average auto-recoveries	Improvement over baseline
baseline 12 bunches (y)	1.2	-
prefire protection bump (b+y)	0.76	1.6x
prefire protection bump (y)	0.77	1.6x
prefire bump+local steering (y)	0.067	17.9x
local steering only (b+y)	0.72	1.7x
56 bunches (b+y)	0.98	1.22x (14.3x compared to 12 y bunches)

- Did not scale well with 56 bunches.
- Current understanding is the bump reduced the population of the high-momentum particles and the orbit steering mitigate the remaining particles from being lost on the taper/MVTX.
- Individual 3-bumps in the arcs from IP8 to IP12 had a 10-20% improvement on MVTX backgrounds depending on the phase+sign.

Task Force Formation

- Task force members: accelerator and detector physicists
- Angelika Drees, Kiel Hock, Guillaume Robert-Demolaize, Chuyu Liu, Henry Lovelace, Travis Shrey, Vincent Schoefer, Brendan Lepore, Lef Skordis, Cameron Dean, John Haggerty, Rosi Reed, Michiko Minty, Haixin Huang, Kin Yip
- Meeting schedule: weekly (met twice so far)
- Goal: identify source, propose and test (simulate) solution candidates
- Note: limited time available, proposed hardware modifications have to fit into the shutdown schedule/available work force

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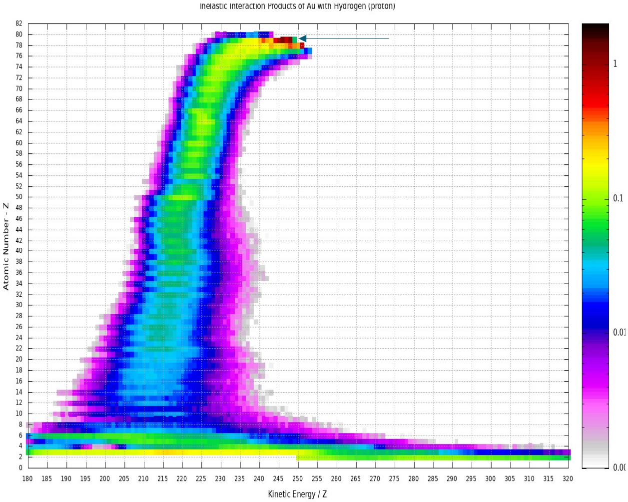
Task Force Goals (details)

With the data available from the end of run:

1. Identify the source of the backgrounds
   - Investigate interactions from residual gas in vacuum
   - Simulating shower generated by Au or Au-h byproducts striking the taper. Include cabling (C. Dean, L. Skordis, A. Drees).
   - Investigate effects of local higher-order magnetic fields on backgrounds (H. Lovelace).
2. Devise a way to mitigate the losses at sPHENIX
   - Studies performed indicated losses were from off-momentum particles.
   - Create non-zero dispersion in a warm section and move the (blue) mask to that (yellow) location (A. Drees, C. Liu, G. Robert-Demolaize).
   - Produce more detailed tracking and ensure the solution is suitable (G. Robert-Demolaize, K. Hock).
3. Improve instrumentation for faster feedback and monitoring with the MVTX off (J. Haggerty, S. Stoll).

Production of 100 GeV/u Au with residual hydrogen

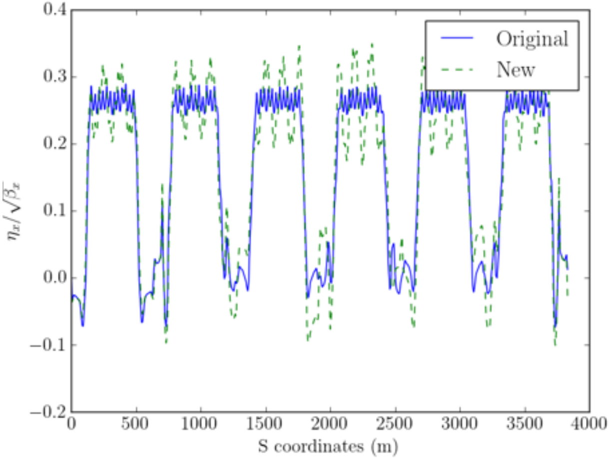


- Investigation of inelastic collision of 100 GeV/u Au on residual hydrogen gas in vacuum
- Large amount of possible byproducts with high Z
- Simulations done with Fluka by L. Skordis
- Future simulations will look at the interaction of beams striking the beampipe taper.

- Au Inelastic Interaction products
- E. Skordis

Mitigating the losses at sPHENIX with a Dispersion Bump

Generation of a dispersion bump at IP12 with what's presently available. (*preliminary*)

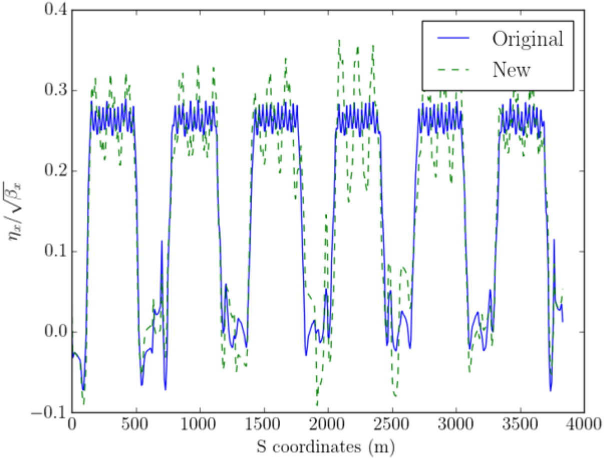


Plots originate at IP6 and move clock-wise and we define the figure of merit as $\eta_x/\sqrt{\beta_x}$

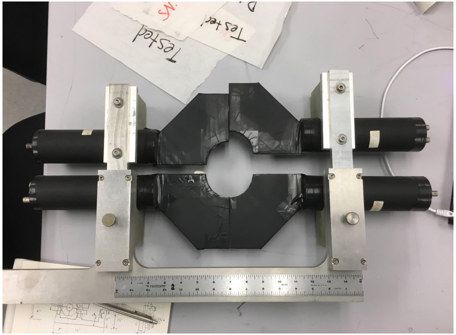
From C. Liu, A. Drees, G. Robert-Demolaize

Mitigating the losses at sPHENIX with a Dispersion Bump II

Generation of a dispersion bump with rewiring of the γ_T quad needs approval and more discussion, including PS personnel. This particular solution also utilizes the Q89s. (*preliminary*)



Instrumentation Improvements



- Recycling scintillator counters from pp2pp downstream of each taper are being investigated.
- location downstream of 2nd taper requires new (smaller) counters
- Having them rotated at 45° provides LRUD resolution.
- Stacking two at 0° and 45° would provide greater resolution.
- Data rate of 1 Hz.

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From J. Haggerty & S. Stoll

Summary

During the run:

- Daily studies from its discovery to diagnose the cause of backgrounds, and mitigate its effect.
- The best achieved reduction used a combination of local steering at IP8 and the prefire protection bump, a factor of 10x reduction with 12 bunches.
- This solution scaled with increased intensity up to 56 bunches, not usable for sPHENIX in streaming mode.

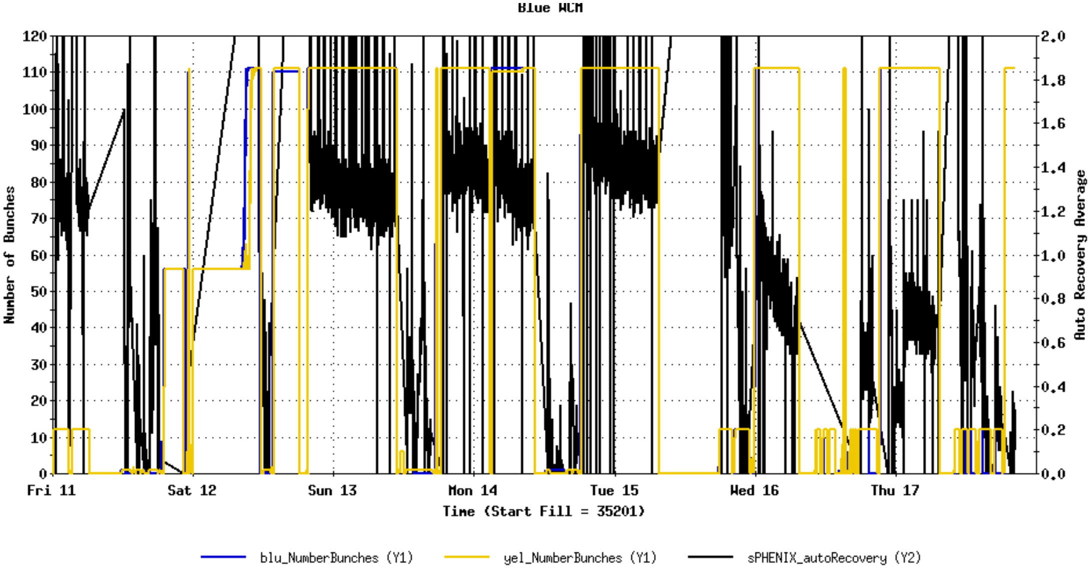
Task force for Run25:

- With the data available, simulations are being performed to identify the source.
- Calculations to find the best solution to mitigate losses that do not cause beam loss in cold sections are being performed.
- Installation of scintillators downstream of each taper will improve the response time and allow optimizations with sPHENIX systems off.
- Regular meetings to monitor progress and ensure a timely resolution.

Thank you

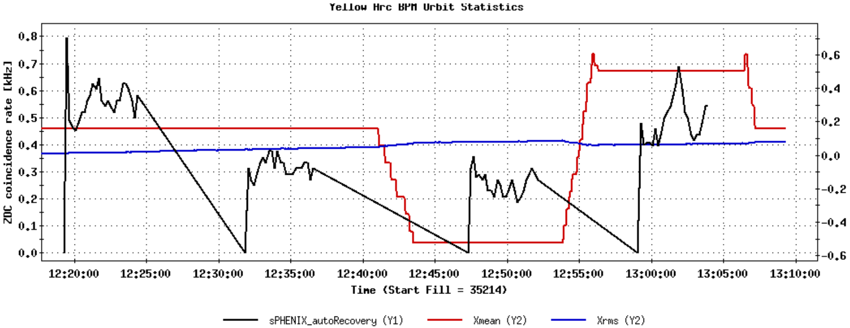
Thank you and questions.

Overview of studies



Yellow only studies I

1x1 B+Y   Yellow, nominal radius   -0.5 mm   +0.5 mm



- Radius change confirmed Friday's results
- -0.5 mm slightly better but beam losses near IR slightly higher. Orbit slightly different than Friday.
- +0.5 mm noticeably worse.
- Repeat study with 12 bunches to have a better measure of losses.
- Insert bump to see if losses can be further improved.

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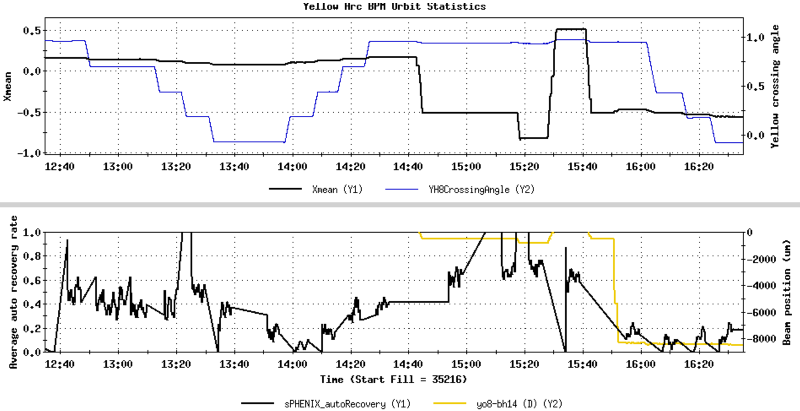
Yellow only studies II

1x1 B+Y   Y crossing θ radius scan   angle scan, -8 mm arc bump



- Radius change confirmed Friday's contrasted with Friday+Saturday's findings.
- sPHENIX background meeting this afternoon.
- Radius change (benign), reduced crossing angle (1 mrad) and small bump at yo8-bh14 (-8 mm) largely reduced the backgrounds.

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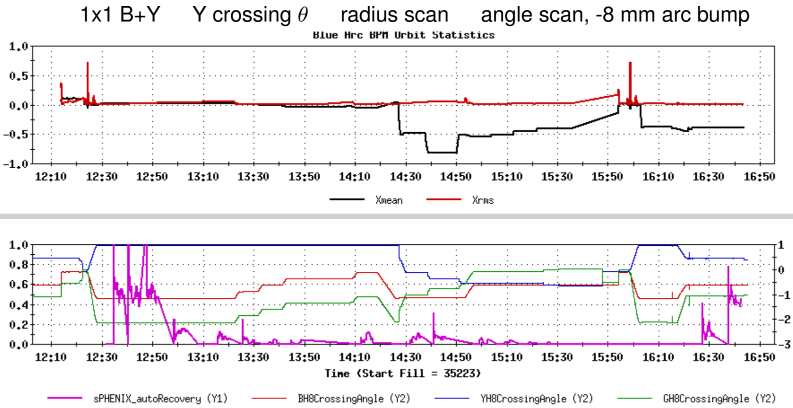
Blue only studies



- Different in radius is suitable for blue.
- Marginal change with changes in crossing angle (1 mrad is an improvement over 2)
- Configuration with -0.4 mm radius, -8 mm bump at yo8-bh14, and 1 mrad crossing angle appears optimal with both beams.

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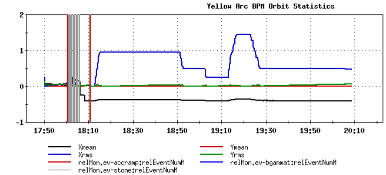
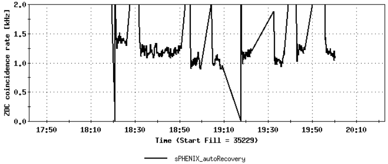
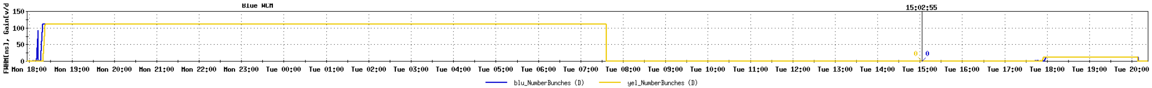
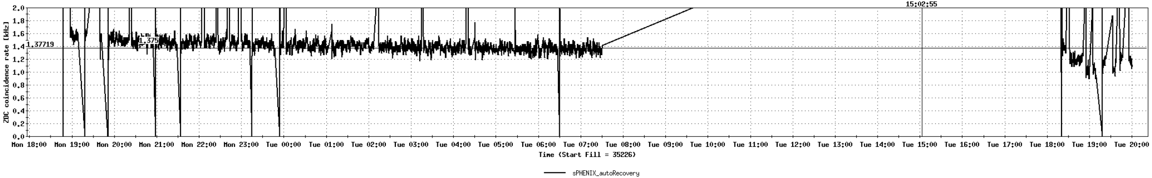
Unsqueeze of IP8

- Dedicated ramp to go into 5 m β^* at IP8 (nominal $\beta^* = 0.7$ m
- -0.4 mm yellow xarcMean ; -8 mm yo8-bh14 bump marginal improvement over 111 bunches.
- Bottom plot shows a comparison of 111x111 bunches for physics (left) with 12x12 with unsqueezed IP8 (right)
- No radial offset better (from this session).
- Switched to triggered mode after 2130.



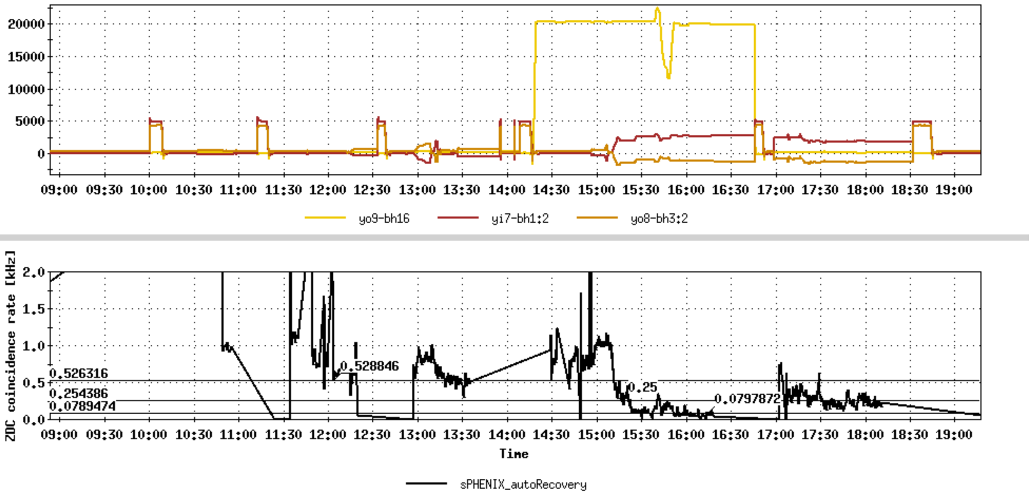






Studies 10/17

IP 10 squeeze, Prefire protection bump, orbit changes without bump



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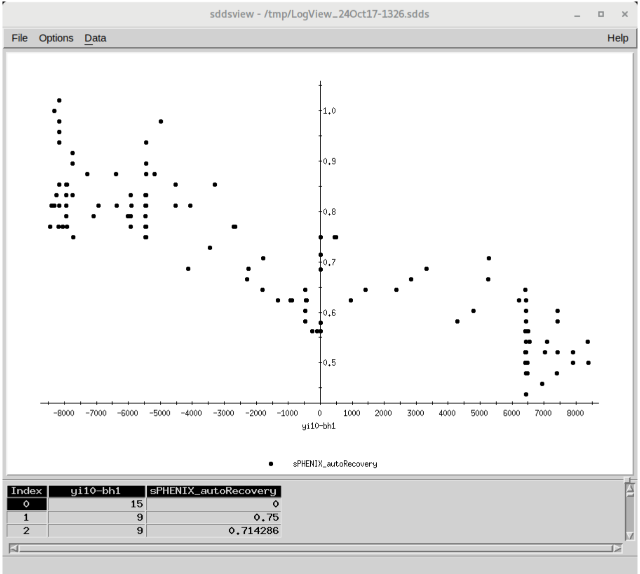
Squeeze of IP10

- Study performed 10/17
- Squeeze of IP10 provided marginal gains over nominal setup
- Addition of a horizontal bump through the IP provided extra gains.



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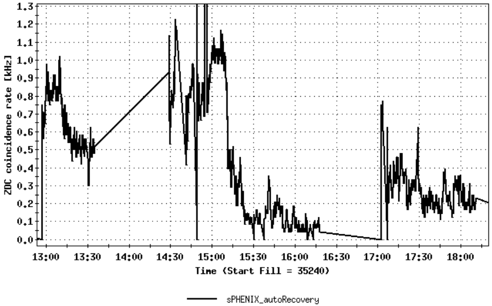
Prefire protection bump

- With bump and local steering were able to get MVTX to near zero auto-recoveries.
- Amplitude of prefire bump changed, found to be optimal.
- Without bump, same local steering, and 3-bumps in the arcs were not able to get to the level of the prefire protection bump (x3 higher)

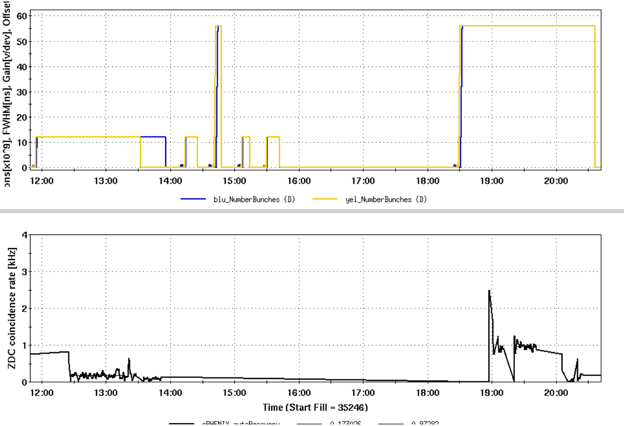


Moving forward, 10/18

We have a solution that works for yellow, need to confirm blue can take the large orbit changes.

- Prefire protection bump is necessary for achieving low MVTX auto recovery rates
- Need to scale this up to 111 bunches and confirm the working point for physics operation
- A more elegant solution should be found during the shutdown.
- How long can we run in this mode? Limited tests prior to the end of run?

Scaling local orbit with PFP to 56 bunches



- The solution for 12 bunches was not suitable with 56 bunches.

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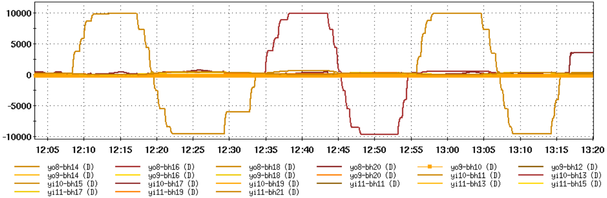
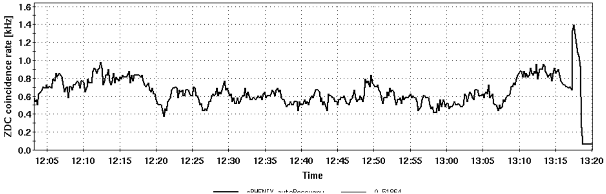
Scan of bumps IP8 to IP12





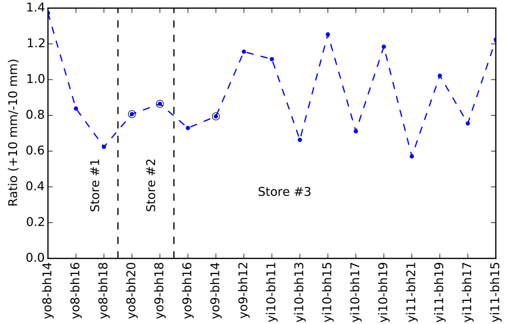
Measurements taken over the course of three stores (first lost due to BPM MPS, third did not have the goal IP8 orbit as previous two)

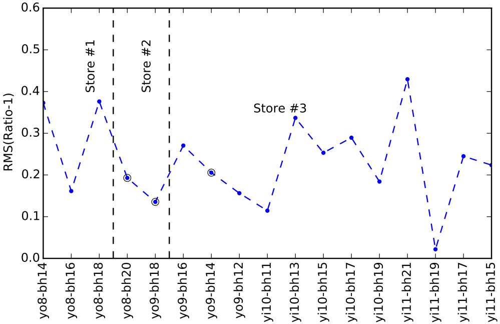
Scan of bumps IP8 to IP12, II

Ratio defined as

$$\text{Ratio} = \frac{\text{auto} - \text{recovery rate}(+10\text{mm})}{\text{auto} - \text{recovery rate}(-10\text{mm})} \quad (1)$$

RMS(Ratio-1) gives the strength of each corrector whereas the ratio gives favor to + or - polarity (+Ratio$\rightarrow$ -bump preference)





Circled data points have data quality issues.