# Proton Beam Scrubbing in RHIC

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APEX2005 Workshop
November 9, 2005

# RHIC Beam Scrubbing Experiment (2005)

Re-evaluate the beam scrubbing effect with stronger beam available now. It is not the only experiment at the time. Cold region pressure rise and heat load are also monitored with the same beam.

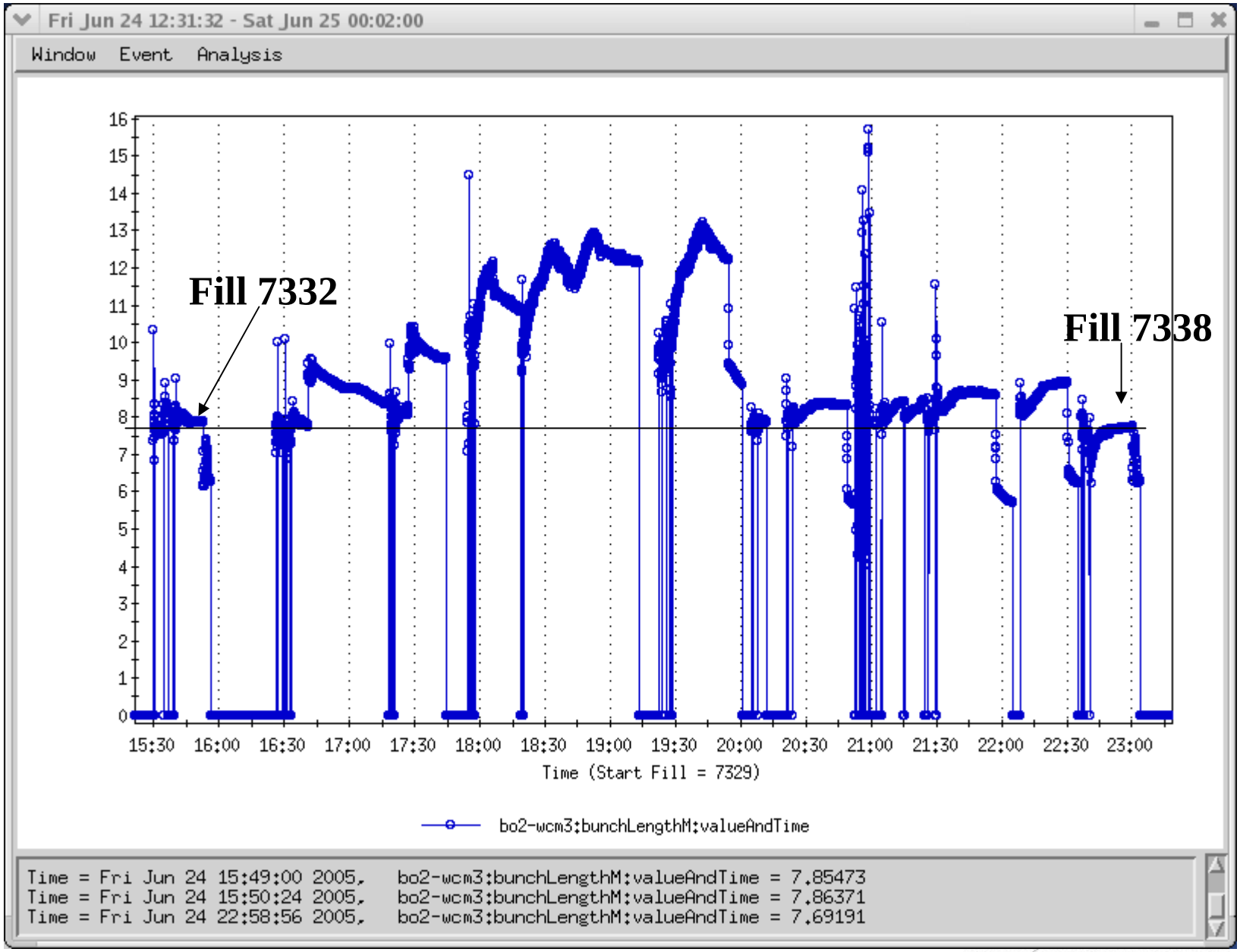
Method:

1. Use 111 bunch pattern in one ring. Starting from $2\times10^{11}$ proton/bunch and eventually reached $3\times10^{11}$.
2. Change rf voltage to keep pressure as high as possible ($P=2\times10^{-6}$ Torr at RF cavities). When the pressure drops, dump the beam and refill.
3. OPM 2.5.2 step 5.1.3 which says for protons each ring must have less then $2.4*10^{13}$ proton at 250 GeV, which means $10^{12}$ /bunch at injection. So we are way below the RHIC intensity safety envelope.

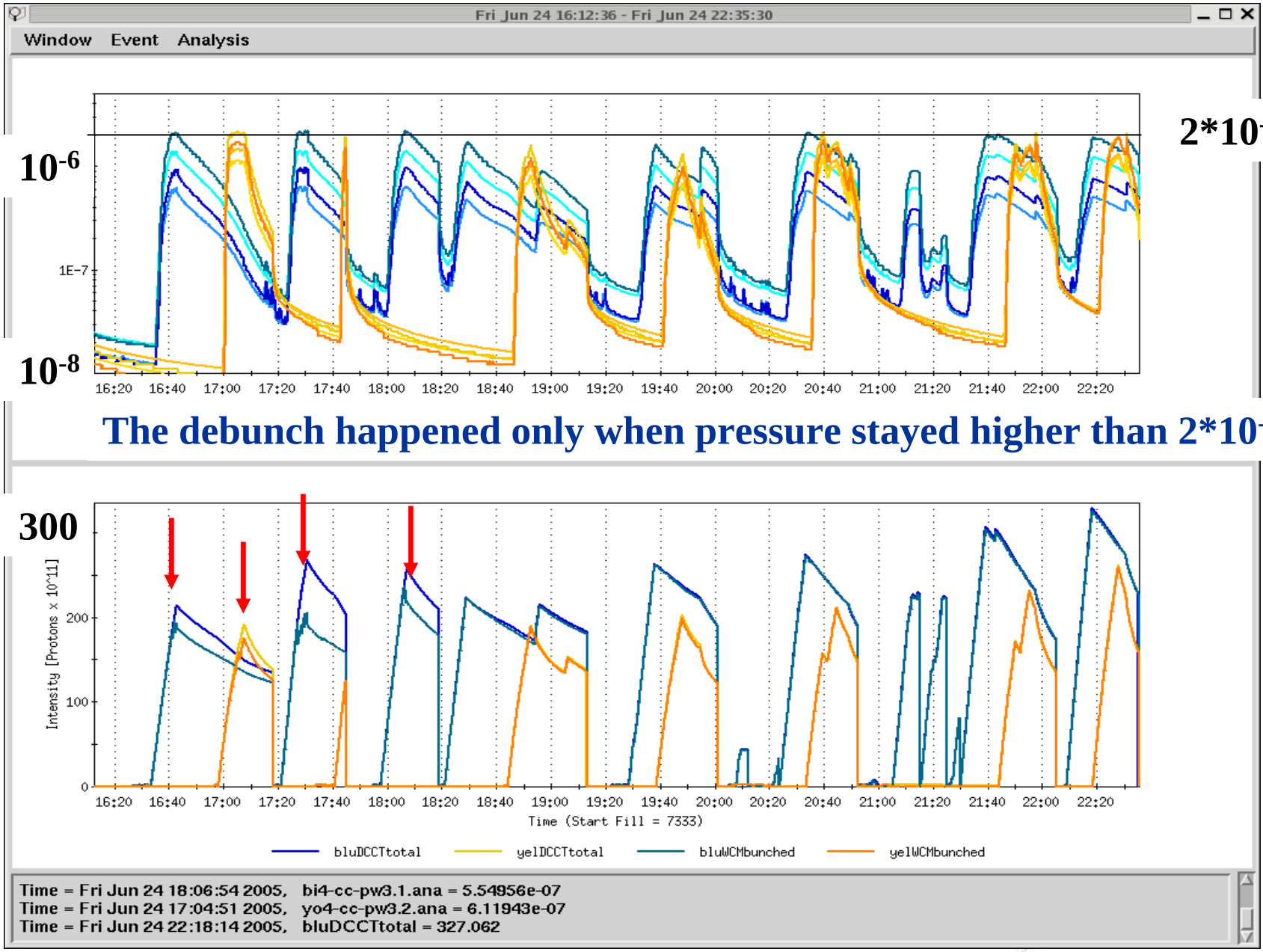
# Scrubbing Setup

- ✓ Between the two similar fills (7332 and 7338), 6.5 hours were spent on scrubbing for both rings. The intensity($2*10^{11}$) in the early part was limited due to beam debunching. It is believed to be cured by scrubbing and intensity was raised to $3*10^{11}$ /bunch.
- ✓ There were two very similar ramps before and after the scrubbing as the attempt to accelerate $1.3*10^{11}$/bunch. They serve as the perfect samples for scrubbing effects.
- ✓ The pressure rise at RF cavities were limited to around $2*10^{-6}$, as it is the preset trip limit for RF cavities. It was only reached at the early part of scrubbing.

# Bunch Length over the Scrubbing Period

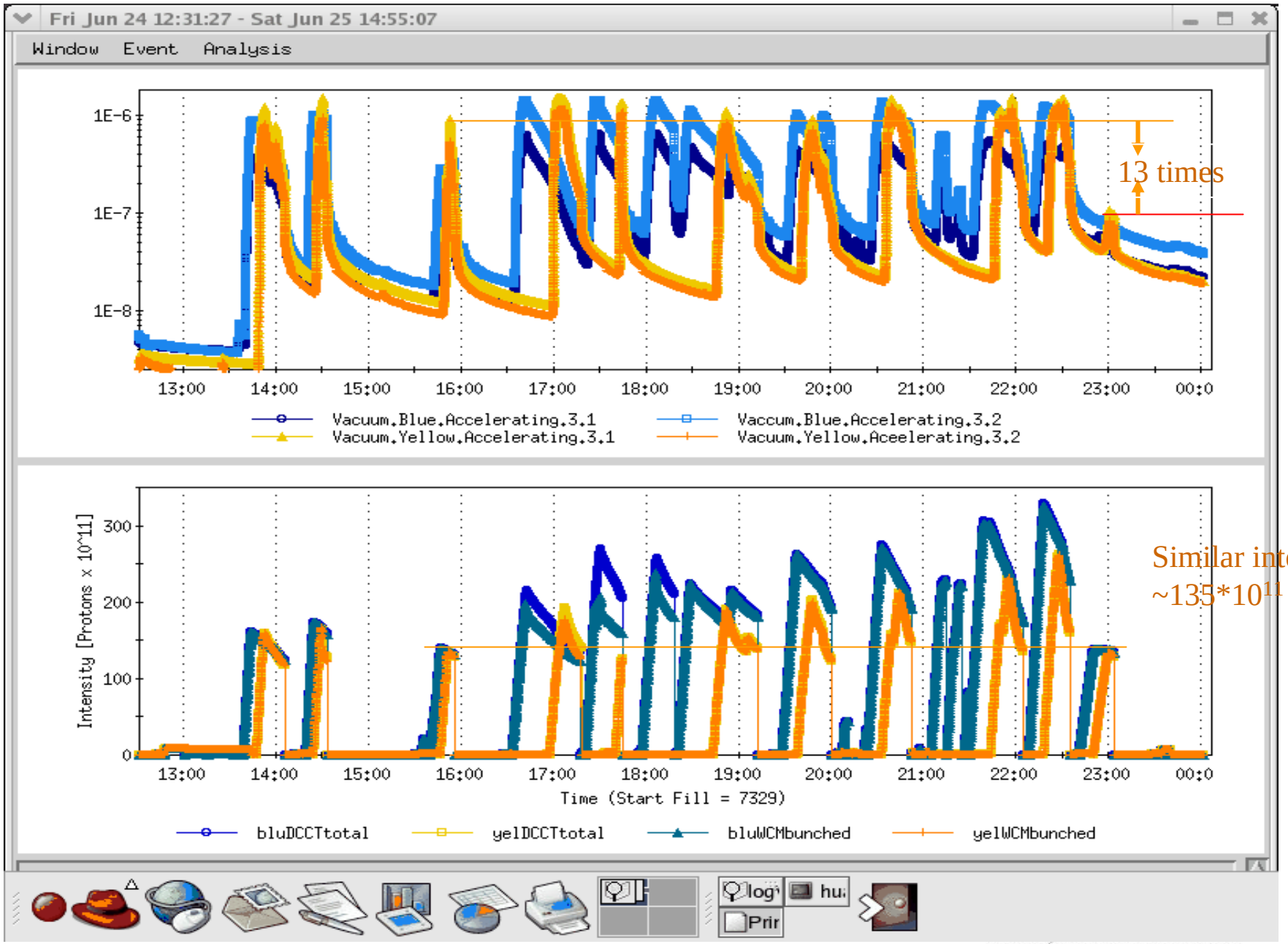


# Scrubbing Beam Intensity and Pressure Rise



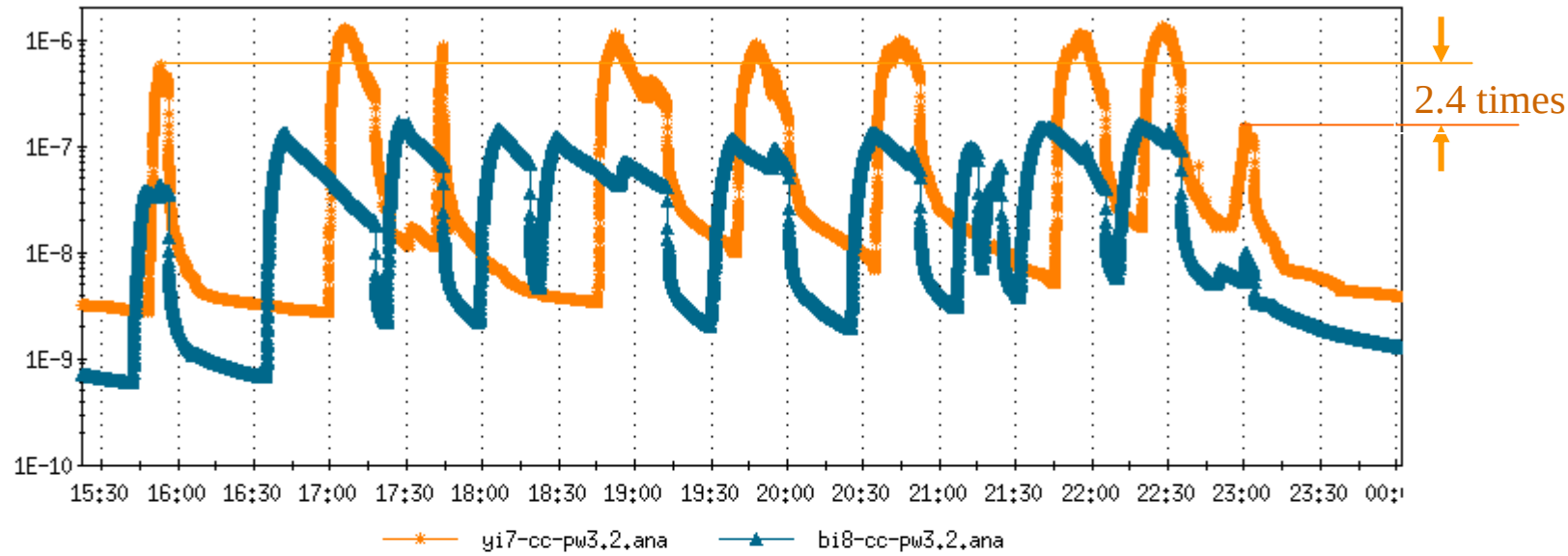

**The debunch happened only when pressure stayed higher than $2*10^{-6}$.**

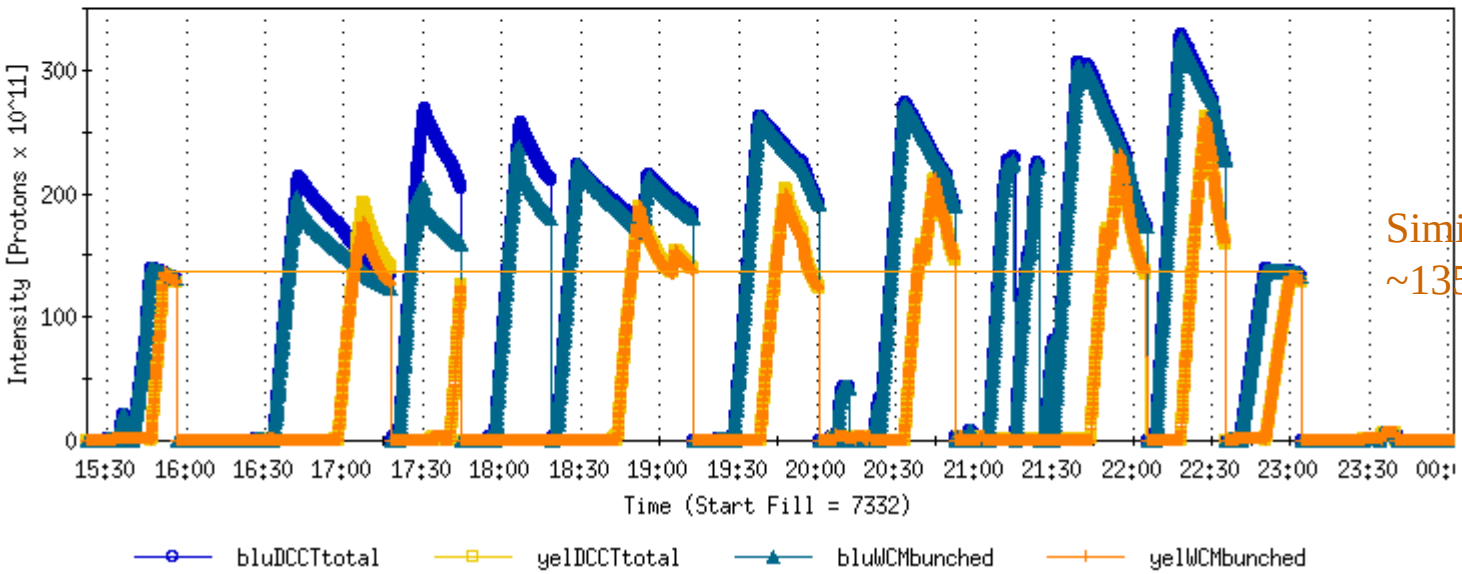
# Scrubbing Effect at RF Cavities




Similar intensity, ~135*10$^{11}$

# Scrubbing Effect at Collimators




Similar intensity, ~135*$10^{11}$



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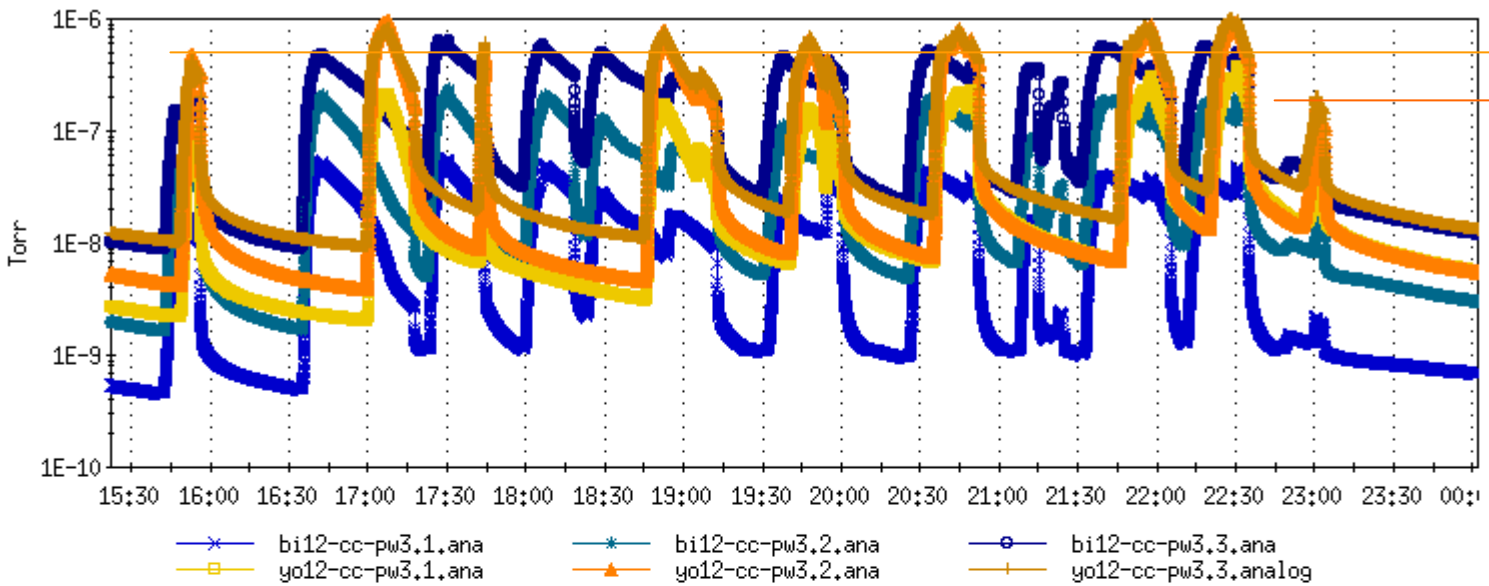
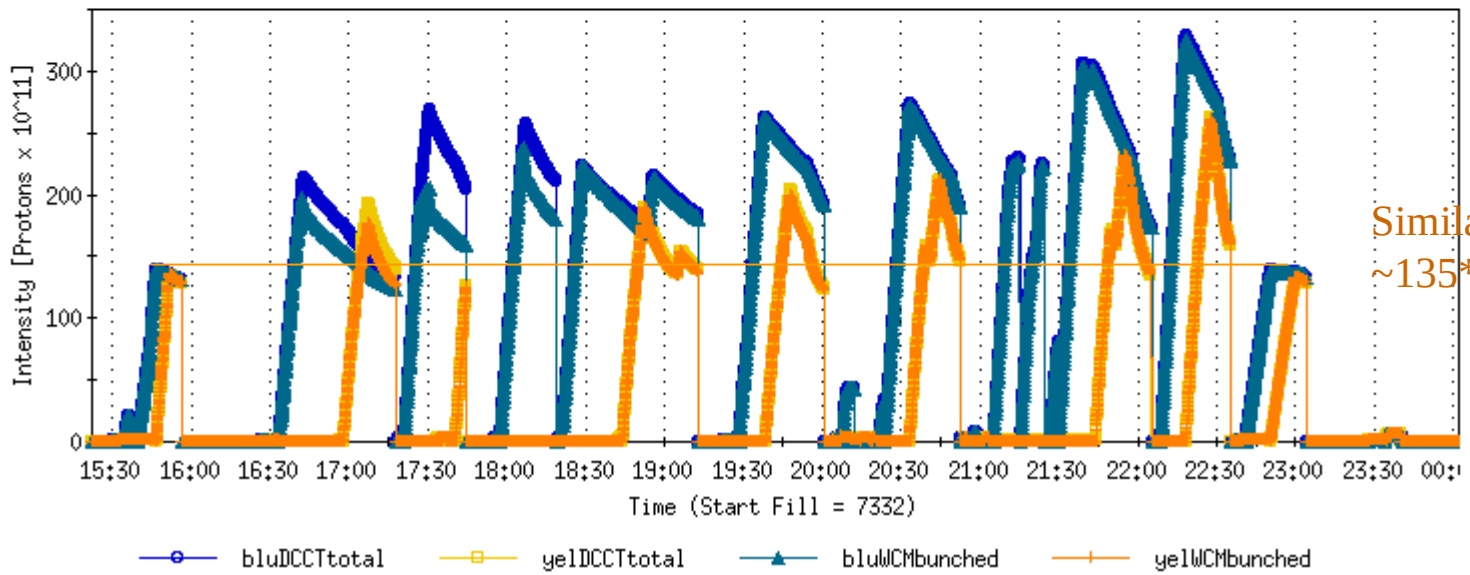
# Scrubbing Effect at Polarimeters




3.6 times




Similar intensity, ~135*$10^{11}$



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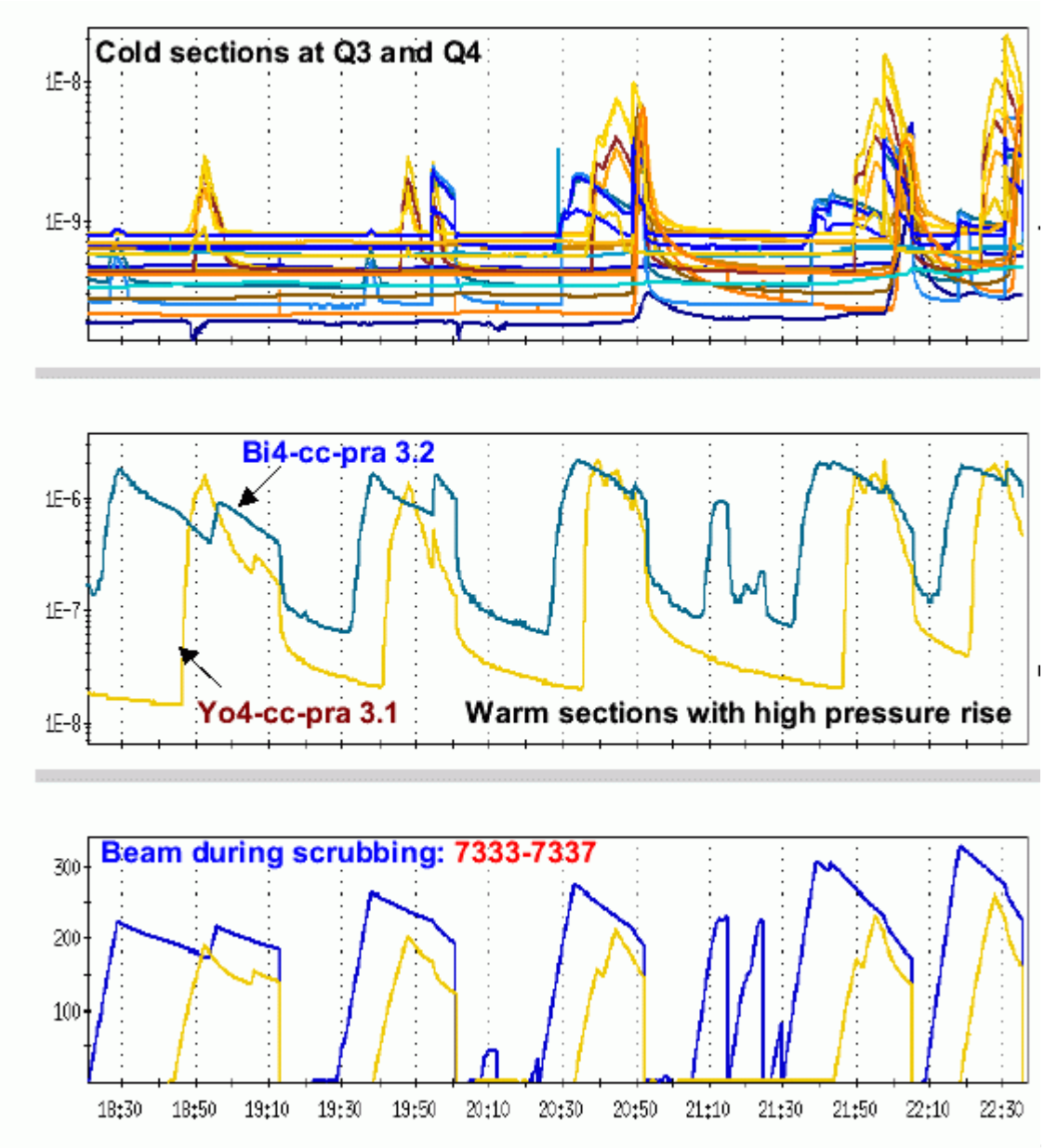
# Scrubbing Effects

| | ΔP (fill 7332) | ΔP (fill 7338) | Dose(hr.Torr)$^2$ | Intensity | Hours |
|---|---|---|---|---|---|
| RF Yellow[1] | $8.14*10^{-7}$ | $0.64*10^{-7}$ | $2.48*10^{-6}$ | $135*10^{11}$ | 2.5 |
| RF Blue[1] | $3.20*10^{-7}$ | $0.14*10^{-7}$ | $4.24*10^{-6}$ | $139*10^{11}$ | 4.3 |
| POL Yellow[3] | $4.10*10^{-7}$ | $1.70*10^{-7}$ | $1.04*10^{-6}$ | $135*10^{11}$ | 2.5 |
| POL Blue[3] | $1.71*10^{-7}$ | $0.43*10^{-7}$ | $1.44*10^{-6}$ | $139*10^{11}$ | 4.3 |
| Col. Yellow | $5.41*10^{-7}$ | $1.47*10^{-7}$ | $2.22*10^{-6}$ | $135*10^{11}$ | 2.5 |
| Col. Blue | $4.20*10^{-8}$ | $1.0*10^{-8}$ | $0.39*10^{-6}$ | $139*10^{11}$ | 4.3 |

1. Take the gauge at Blue cavity 3.2 and Yellow cavity 3.1, where the highest pressure rise is observed.
2. For RF cavities, the doses are calculated from the pressure rise measured in the cavities but the actual scrubbing happened in the beam pipe. Based on the conductance of the beam pipes, the dose in the beam pipe is estimated to be a factor of 1.6 higher.
3. Take the gauges at YO12 pw3.3 and BI12 pw3.3 which are closest to the polarimeter chambers and with highest pressure rises.

# Pressure Rise in Cold Sections




- The pressure rise at cold region is getting higher with stronger beam. No scrubbing effect.
- Warm sections show scrubbing effect (constant pressure rise with higher intensity).

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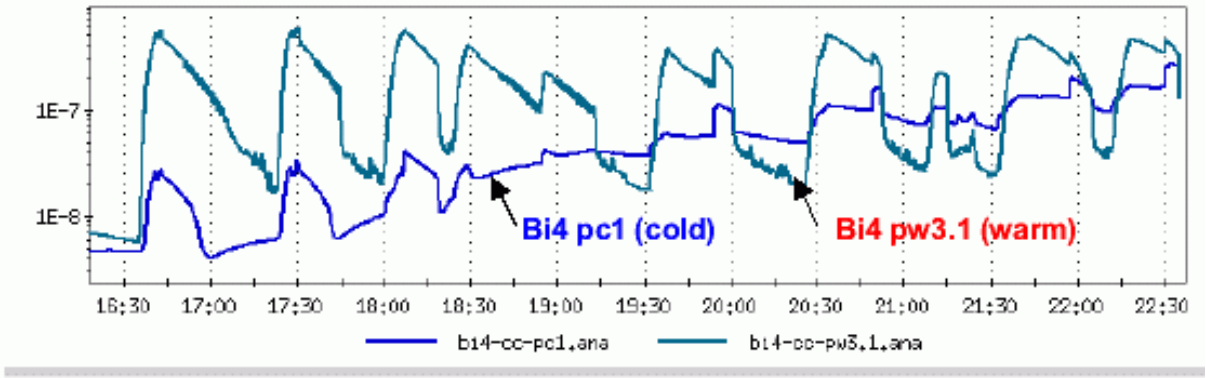
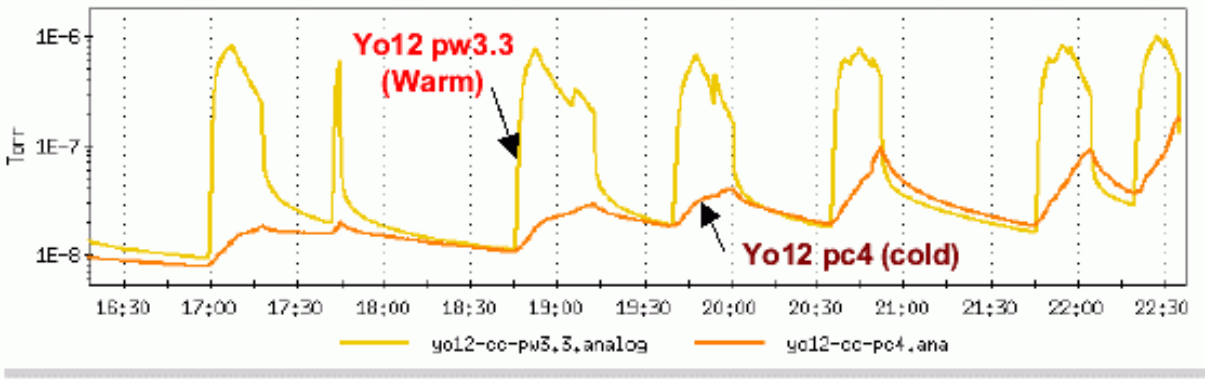
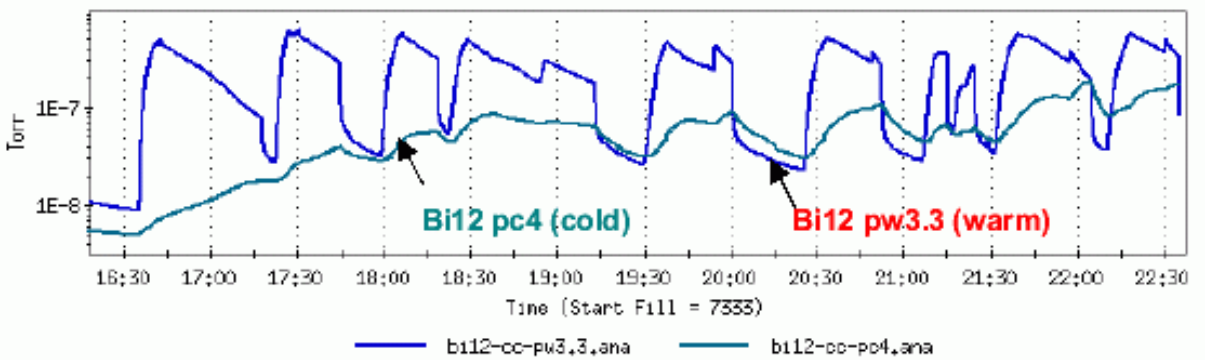
# Pressure Rise in Cold Sections (2)




- **Total six locations with highest pressure rise of $5*10^{-8}$ to $2*10^{-7}$ Torr at Q3 and Q4. All look like due to ($H_2$) migration from nearby warm section pressure rise.**

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# Summary

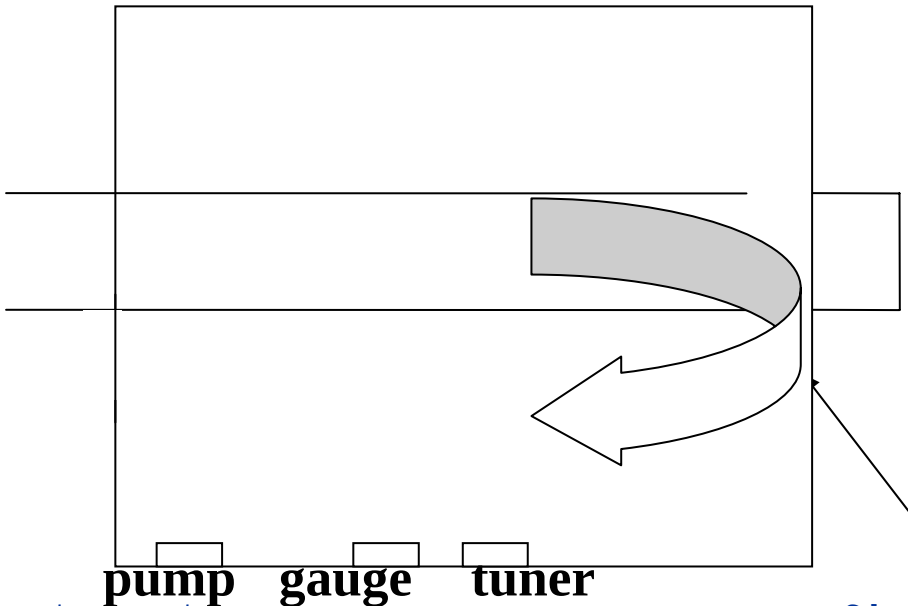
- ✓ It is quite encouraging that intensity achieved at RHIC injection has gain a factor of six in last four years (mainly baking and NEG pipe).
- ✓ Practically, a six hours scrubbing of both rings reduced the pressure rises at cavities by 13 (yellow) and 23 times (blue), respectively. This is achieved with 1-2*$10^{-6}$ pressure scrubbing. For polarimeters where pressure rise was lower, the pressure rise reduction is 2.4 times for yellow and 4.0 time for blue.
- ✓ Potential applications: condition the beam pipe inside rf cavities or reduce pressure rise at polarimeter chambers after chamber opening.
- ✓ Use >3*$10^{11}$/bunch intensity in the future to shorten the scrubbing time? Safety issue should be evaluated first (BPM electronics already moved, there is no known leakage current increase in polarimeter Si detectors either).
- ✓ There is no visible heat load in cold sections, there is also no or little scrubbing effect there.

# Backup Slides

# RF Cavity

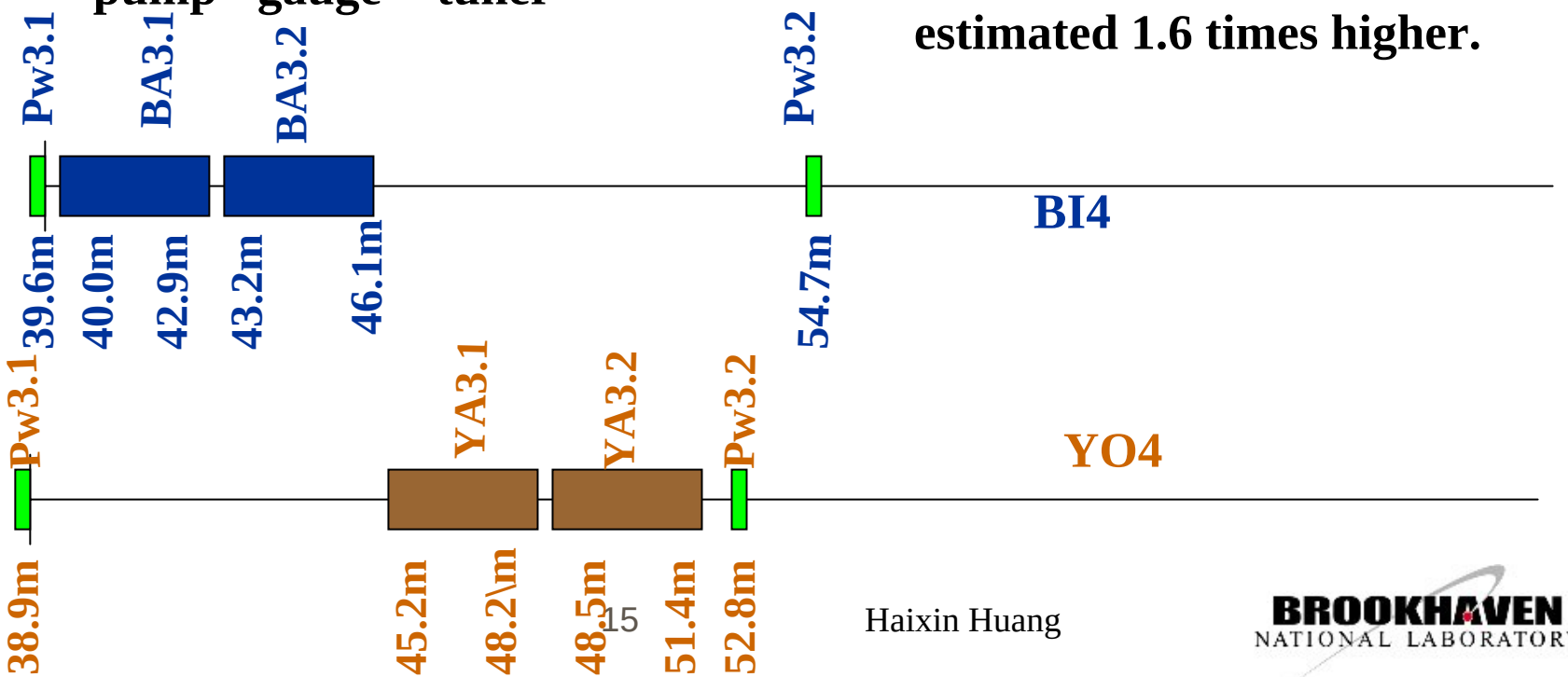
- ✓ The debunching in the first a few fills were associated with the rf voltage drops. Is it due to spark (vacuum related ) or tuner problem?
  1. RF tuners of B3.2 and Y3.1 were malfunctioning and they have been fixed during this shut down. The proton intensity at the time was the highest so far and consequently the tuners had to go to new positions which might cause mechanical jams. However, in later (after 7333) fills, the new tuner position did not cause problem.
  2. The high vacuum pressure rise caused the sparks.
- ✓ In both rings, there seems to be a pressure threshold for the voltage drop to happen, which pointed to vacuum as the cause. The time sequence also suggests that pressure rises first.
- ✓ Even though only two rf tuners were malfunctioning, the tuner position jumps for all four cavities are similar.
- ✓ Vacuum pumps for Blue and Yellow cavities 3.2 were off during the study. But it is not a big factor for pressure rises.
- ✓ The source of this pressure rise can only be due to beam pipe electron clouds in the beam pipe. Due to the structure of the rf cavities, the actual pressure rise in the beam pipes are even higher (1.6 times).

# RF structure

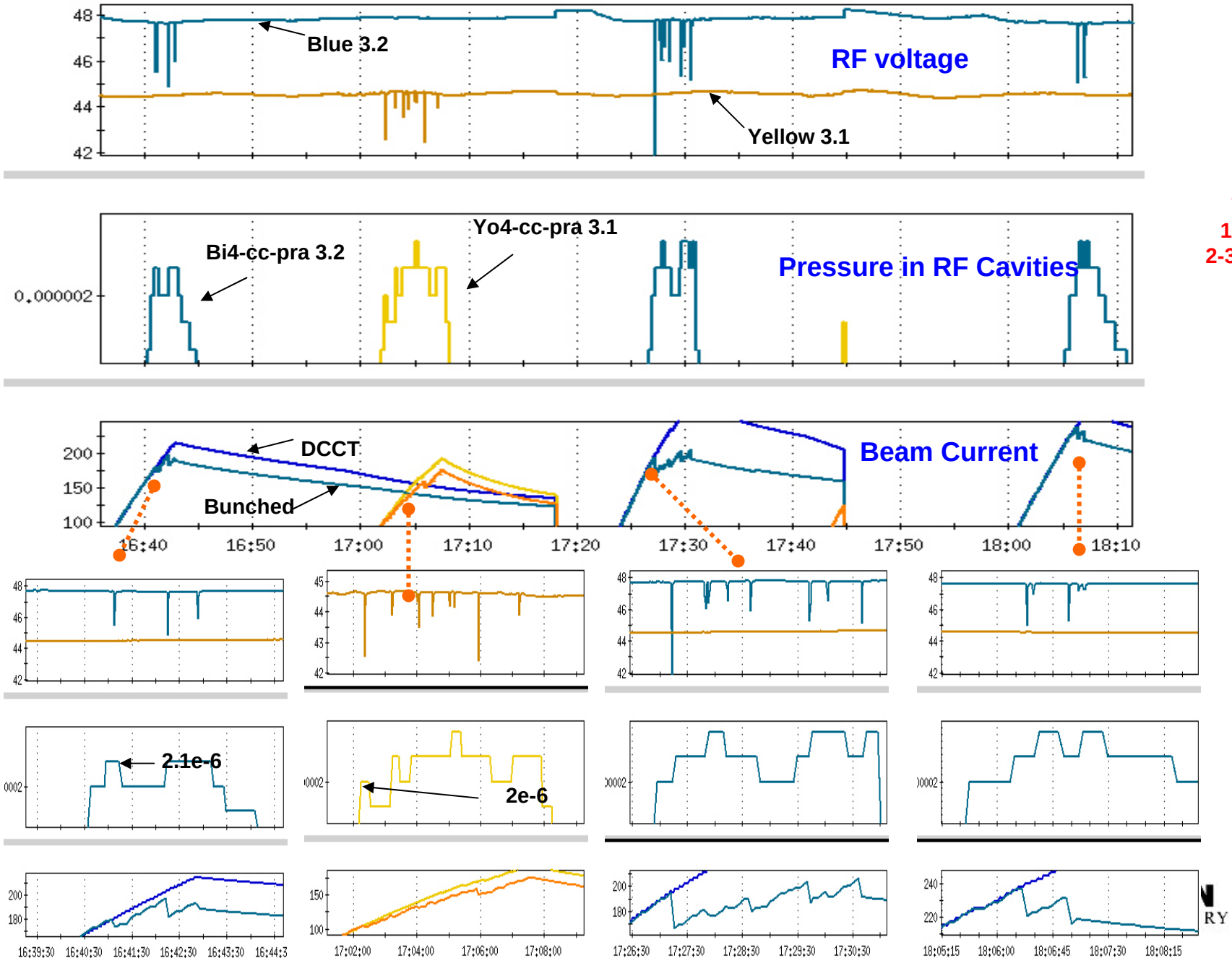



**Beam pipe**

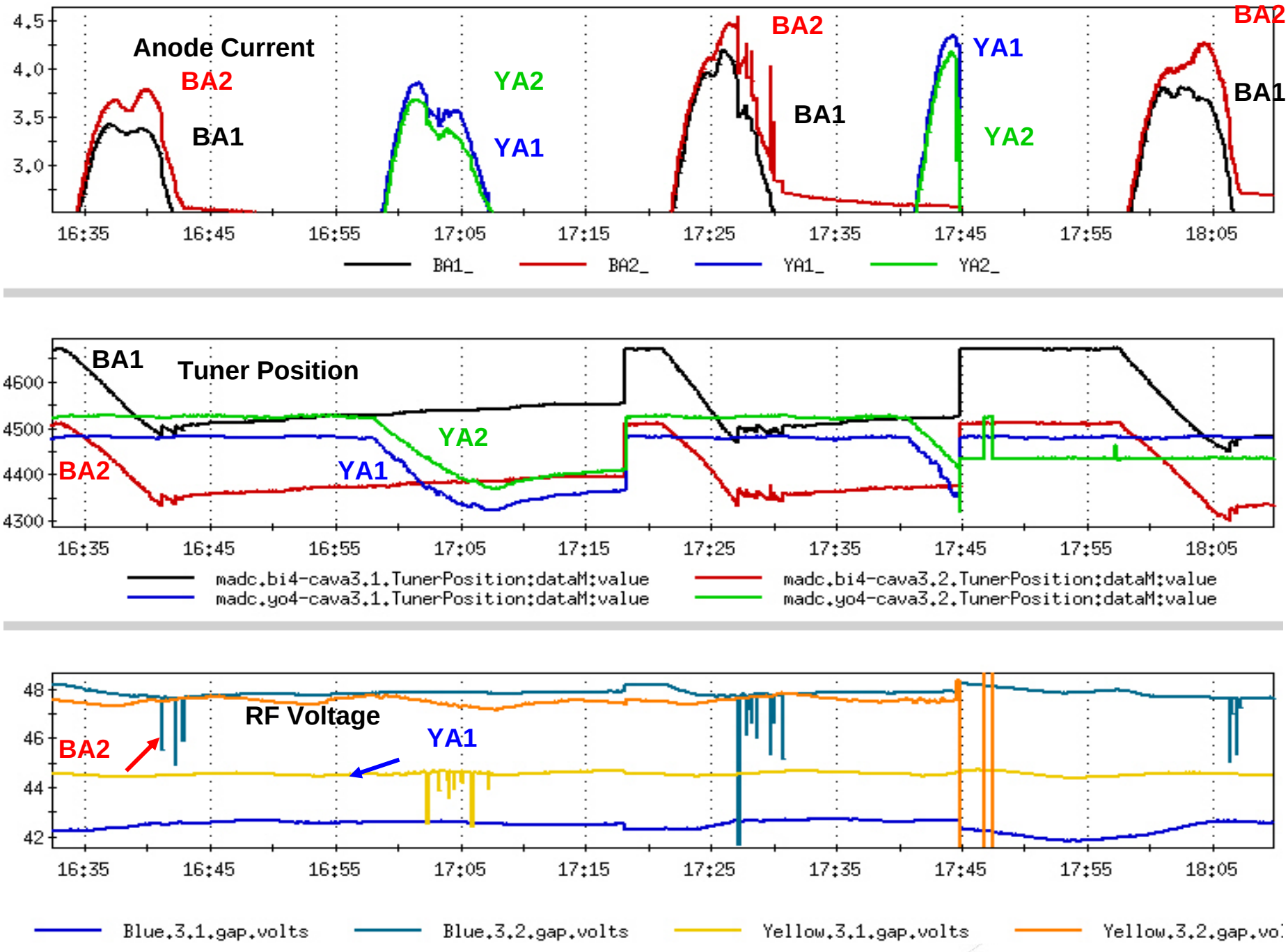
**Pressure rise inside the beam pipe is estimated 1.6 times higher.**



# RF Voltage vs Pressure in Cavities - 7333




7333
110-bh
2-3e11/bh


Anode Current
BA2
BA1
YA2
YA1
BA2
BA1
YA1
YA2
BA2
BA1
4.5
4.0
3.5
3.0
16:35
16:45
16:55
17:05
17:15
17:25
17:35
17:45
17:55
18:05
BA1_
BA2_
YA1_
YA2_
BA1
Tuner Position
BA2
YA2
YA1
4600
4500
4400
4300
madc.bi4-cava3.1.TunerPosition:dataM:value
madc.yo4-cava3.1.TunerPosition:dataM:value
madc.bi4-cava3.2.TunerPosition:dataM:value
madc.yo4-cava3.2.TunerPosition:dataM:value
RF Voltage
BA2
YA1
48
46
44
42
Blue.3.1.gap.volts
Blue.3.2.gap.volts
Yellow.3.1.gap.volts
Yellow.3.2.gap.vo

# Thoughts on Conditioning RF Cavities

- ✓ The source of the pressure rise near the cavities are e-cloud in the beam pipe inside the rf cavities. This pipe can not be conditioned by regular conditioning done before beam starts. Moreover, these pipes can not be NEG coated as it is hard to activate them. The scrubbing is the only way to condition them.
- ✓ As demonstrated, the e-cloud inside the beam pipe poses a more serious problem than the cavities themselves, NEG coating the rf cavities may not be helpful to fight this pressure rise.