RHIC Cu-Cu Machine Performance

overall results

- **delivered 15 nb^{-1}** in the **100 GeV/u** run (**HE**), more than twice the goal of 7 nb^{-1}
- **exceeded maximum luminosity projections**
- **set&ramp-up time** with beam **2 ½ weeks** (4 weeks planned)
- 2 experiments reached the **HE physics goal in 8 weeks (**the other 2 a significant fraction)
- successful **2 weeks** at **31.2 Gev/u (LE),** set-up **2 days**
- successful **1 day run** at **injection 11 GeV/u (IE)**

*despite initial hurdles: **budget** vagaries, D6 and bus-2-bus short →**warm-up and repair**, **aperture** obstruction….*

outline

- **overall machine performance**

  chronology, injectors, integrated lumi, lumi/week, uptime
  comparison 100 GeV/c (HE) and 31.2 GeV/c (LE)
- **performance limitations**

  on bunch intensity, number of bunches
- **run-5 new developments, system highlights**

  most relevant to operations

chronology

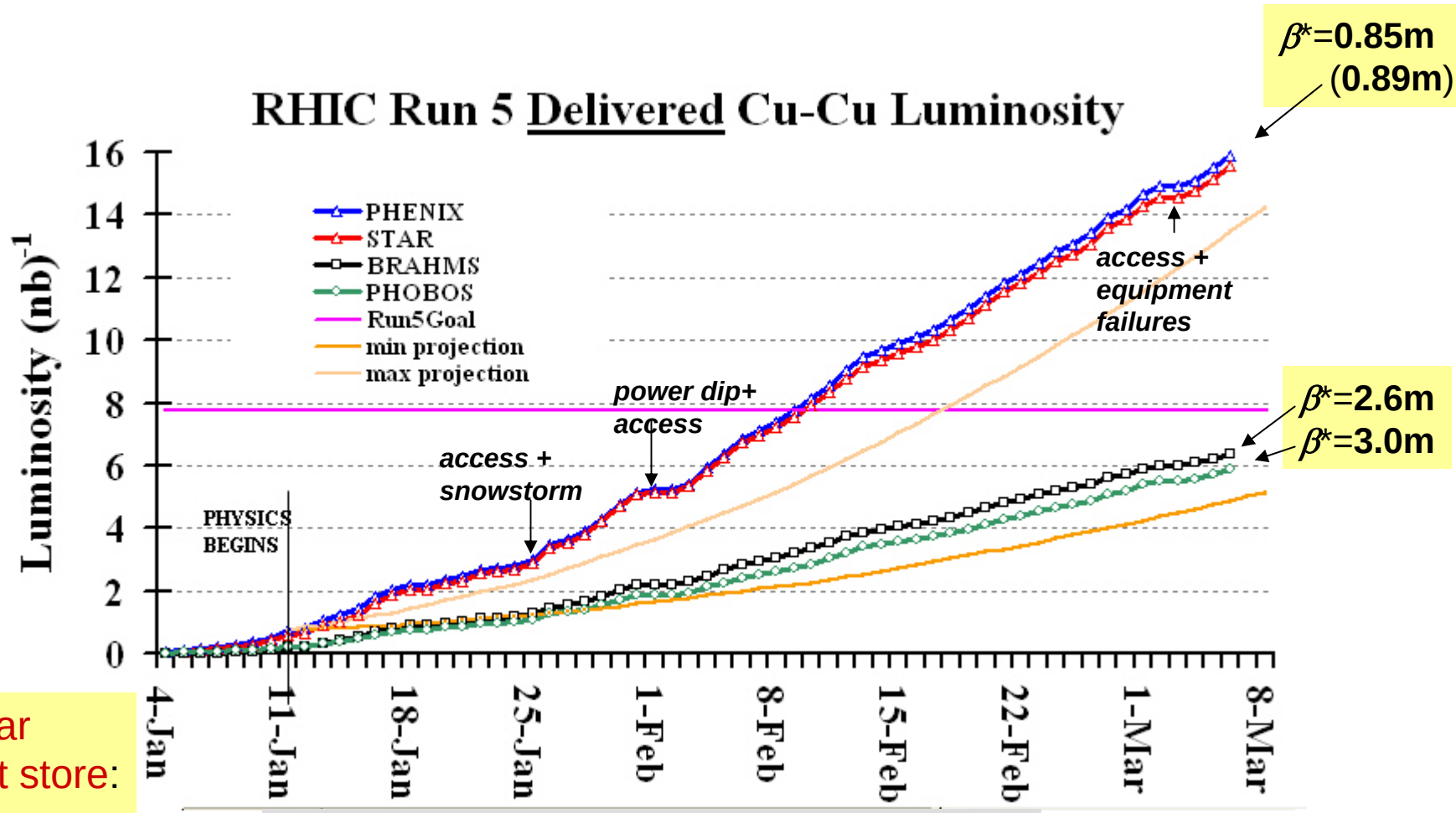
June 7-9	Retreat
Aug 16	choice of ion
Sep 7	start **cool-down to 80K** (on hold – budget uncertainties)
Nov 15	start **injectors set-up** for Cu
Nov 18	start **cool-down to 4 K**
Nov 22	beam circulating at injection in blue (54 minutes!)
Dec 1st	**shorts** discovered in yellow (10: D6, 12: Q3 splice)
Dec 4-21	warm-up, repair, cool-down
Dec 23-25	re-start beam ops, blue ramp with 95% transmission
Tue Dec 28	**set-up starts both beams** → yellow obstruction
Dec 31	both rings at store
Tue Jan 4	**ramp-up starts** – **collisions overnight**
Tue Jan 11	**HE physics starts** – with 28x28 4.5e9
Mar 7-22	**LE set-up** (2.5 days) and **physics run**
March 23	**injection run**

2 weeks

Injectors - highlights

- **set-up** injector complex for Cu: ~ **1 week**
- **steady** delivery of required **4.5 - 5 x 10^9** Cu ions/bunch
- up to **7 x10^9** ions/bunch delivered for experiments
- transverse emittance **9-11 π mm mrad**
- longitudinal emittance **0.4 eV sec/u**

Integrated luminosity 100 GeV/u



calendar time at store: **52%**

Cu-cu cross section measured at 2.6 barn

projections vs. performance

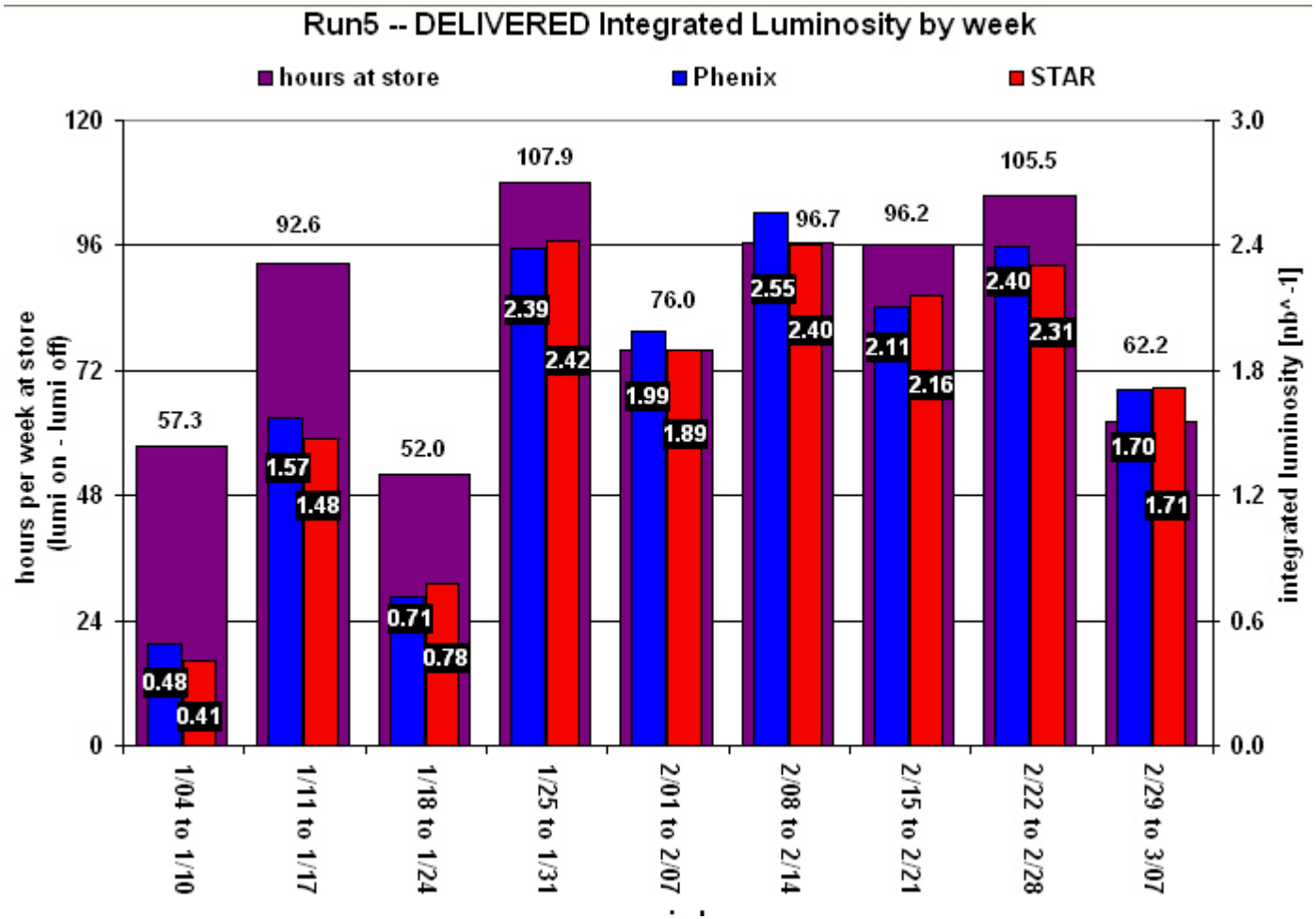
Factors for exceeding projections (HE):

- β^* squeeze **1m** (*measured 1.1m*) → **0.85** (*0.89*)
- optimization intensity, #bunches
- luminosity ramp-up faster than the model used in the projections
- accurate prediction of lumi slope

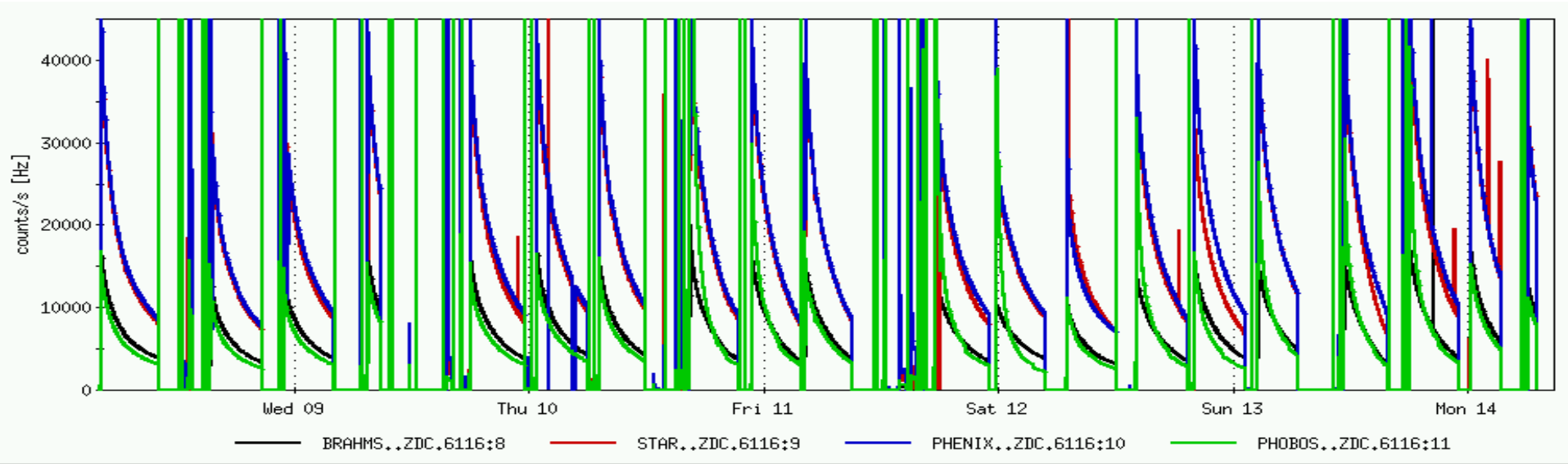
Big (luminosity) Dippers: (visible dents in lumi plot)

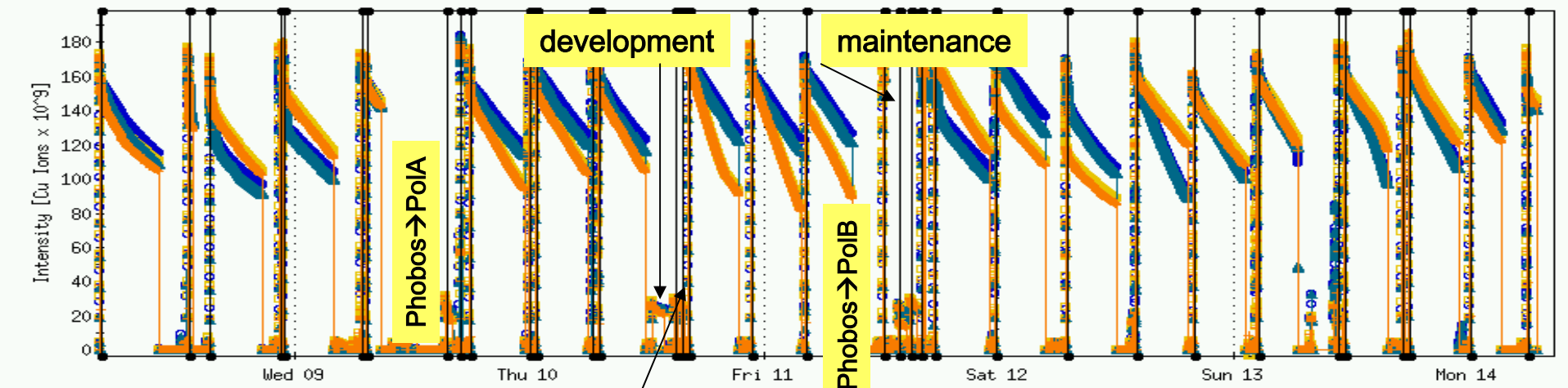
- access + snowstorm
- power dip + access
- access + series of ensuing equipment failures

Luminosity / week

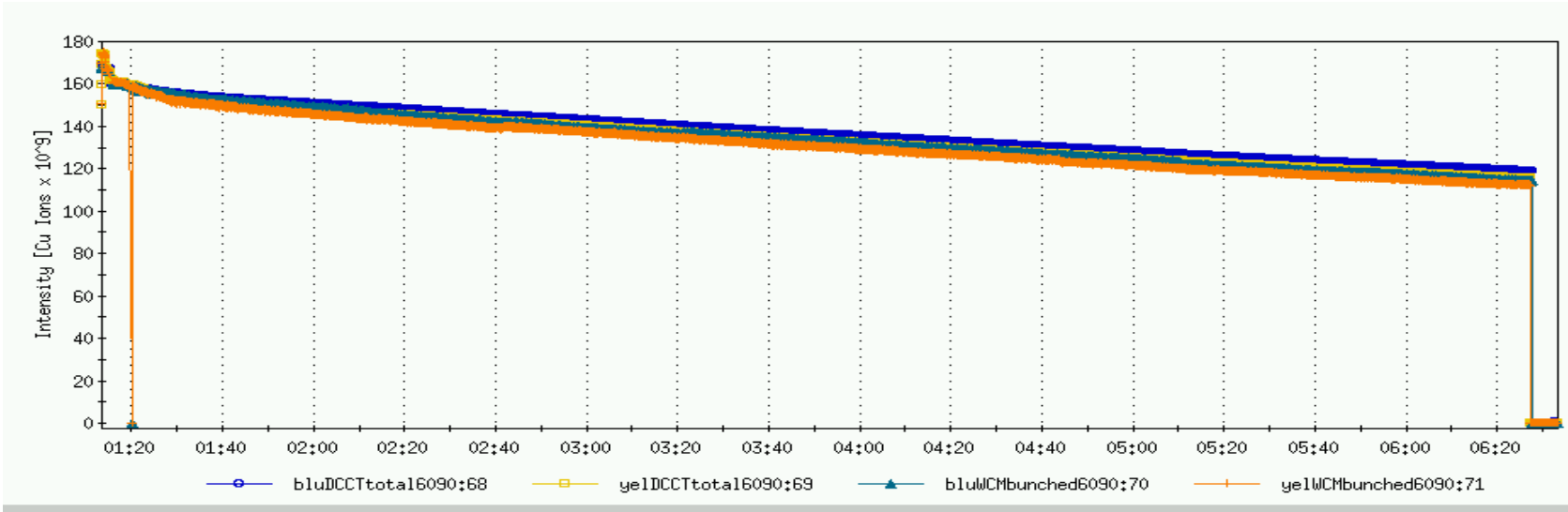


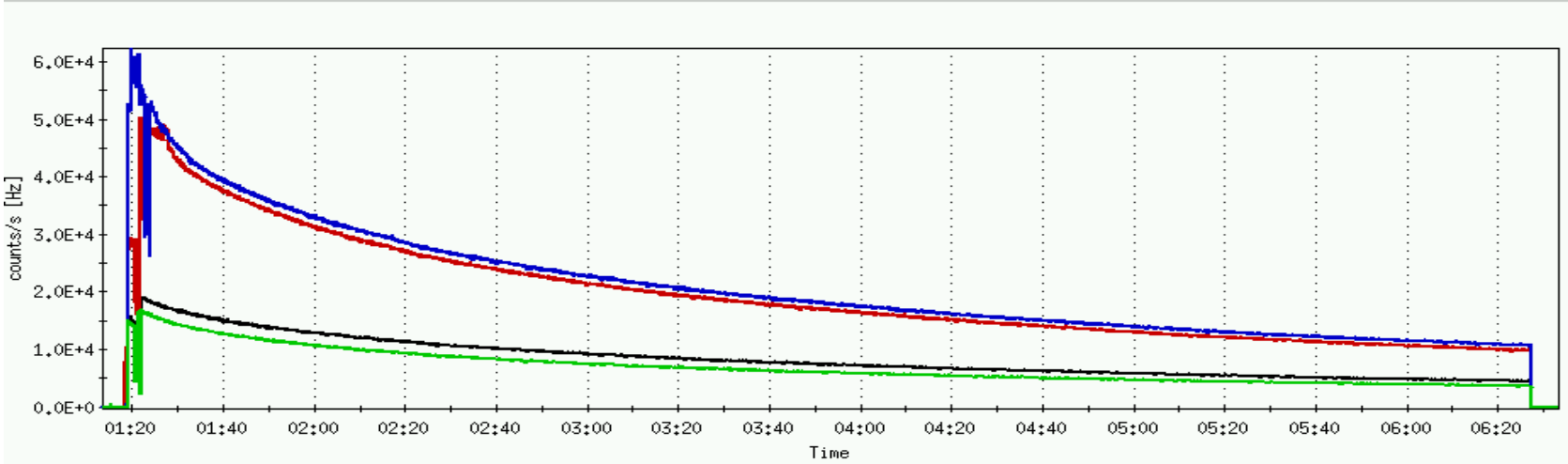
Rates, intensities – week 5



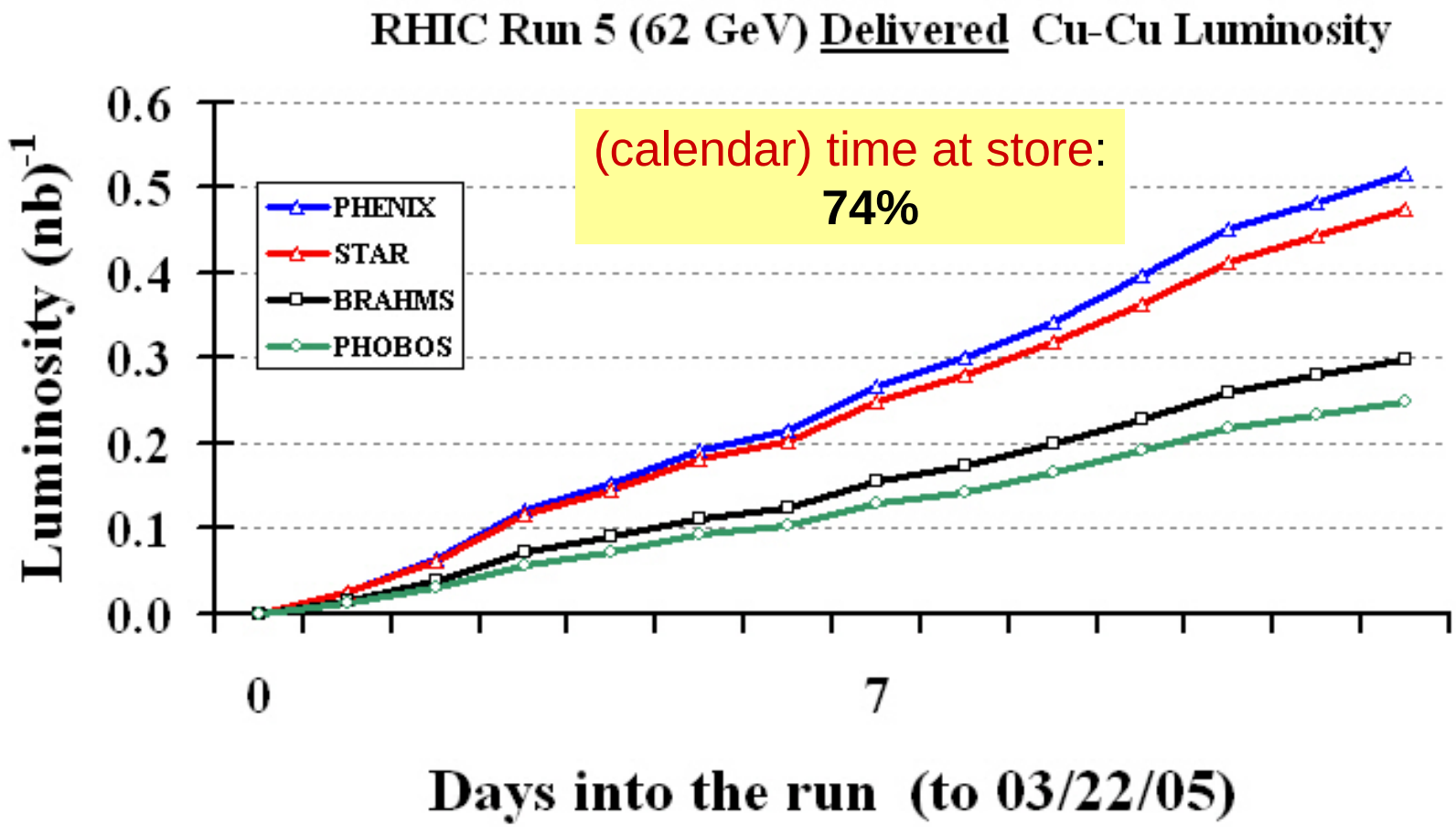


Cu-Cu store 100 GeV/u





Integrated lumi 31.2 GeV run



Comparison HE vs. LE Cu run

Observables

- **Reliability, time at store** HE: 53% LE: 74%
- **luminosity lifetime** HE: 3.5 h LE: 6 h
- **time between stores**

Variables: machine parameters

(almost the same #bunches 37-41, transmission HE~95%, LE ~ 85-92 %, same transition set-up)

- **bunch intensity**: HE 41x 4.5e9 LE: 37x3.8e9
- **beta*** HE: 0.85m LE: 3m
- **energy** HE: 100 GeV/u LE: 31.2 GeV/u

HE vs. LE: Reliability factors

Balance **machine performance** (←push machine parameters)

machine reliability (← more conservative parameters)

Bunch intensity

- Losses on ramp, permit pulls
- Beam decay at store, tuning, collimation
- Beam-beam, luminosity lifetime
- single bunch instabilities

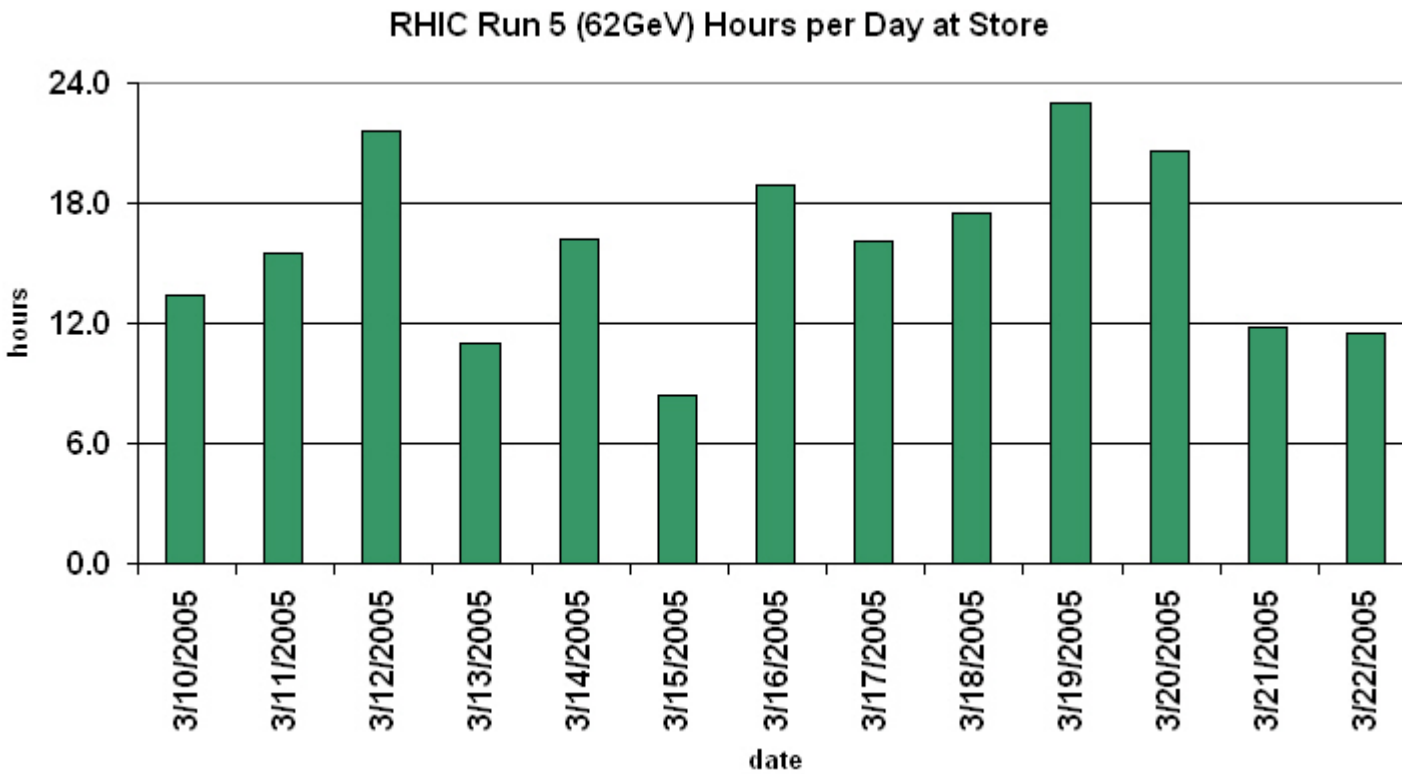
Beta squeeze

- Losses on beta squeeze, permit pulls
- Aperture, losses at triplets

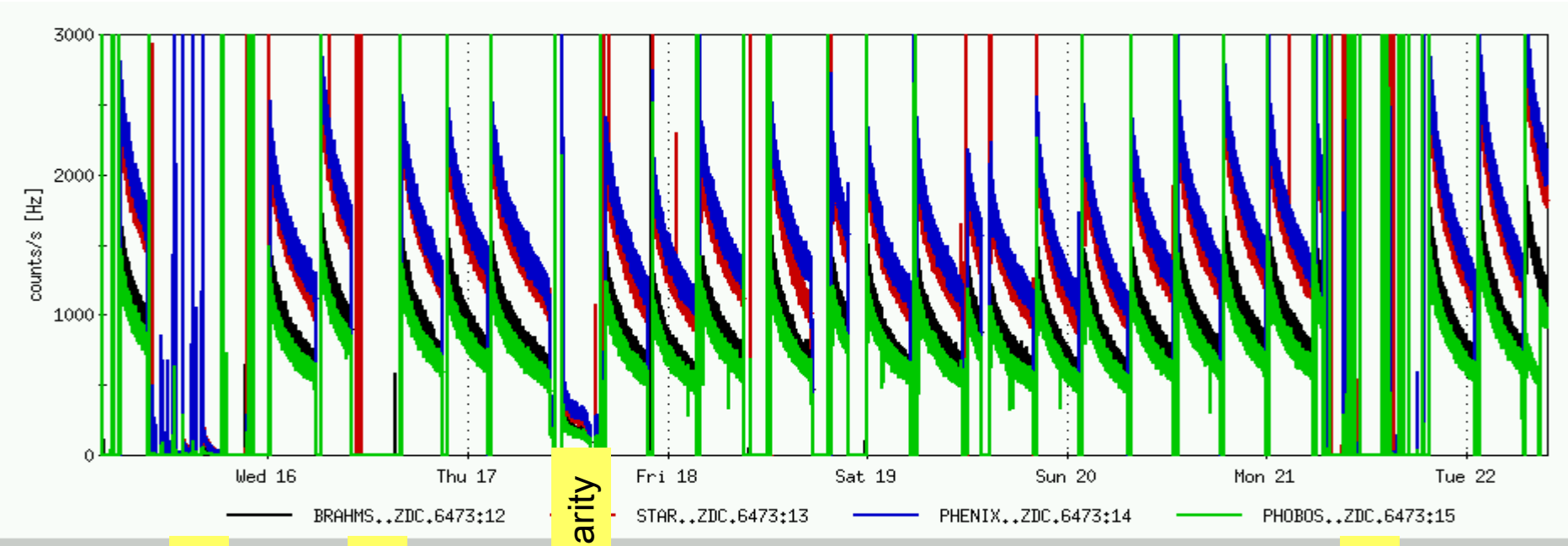
Energy

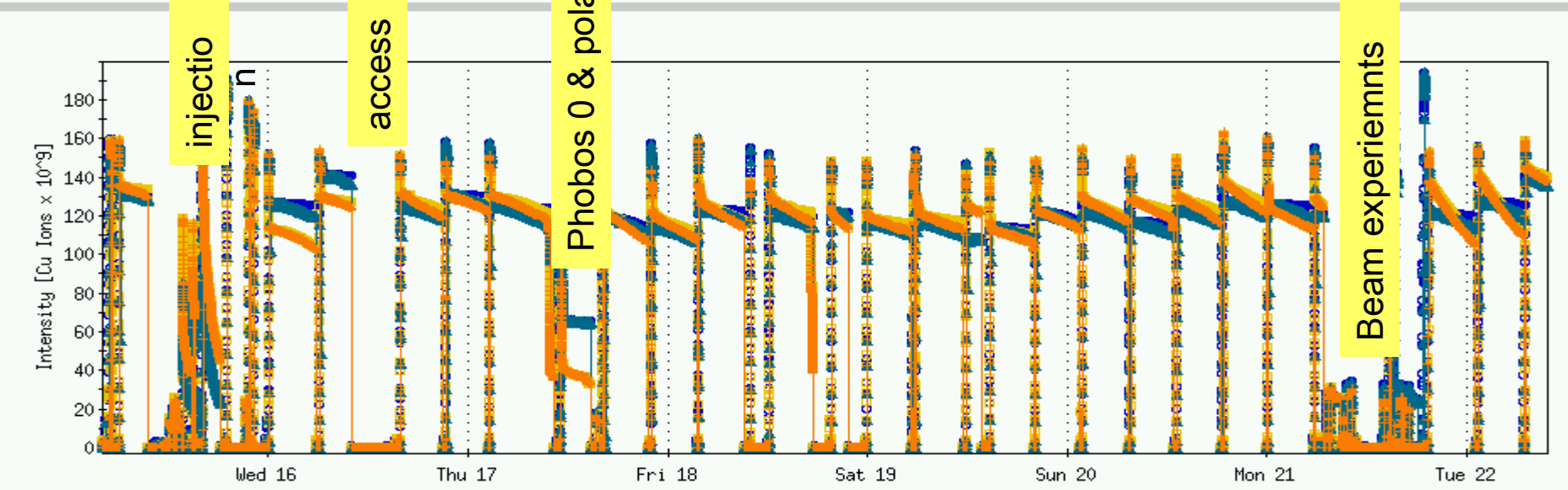
- shorter time between stores

Hours at store - LE

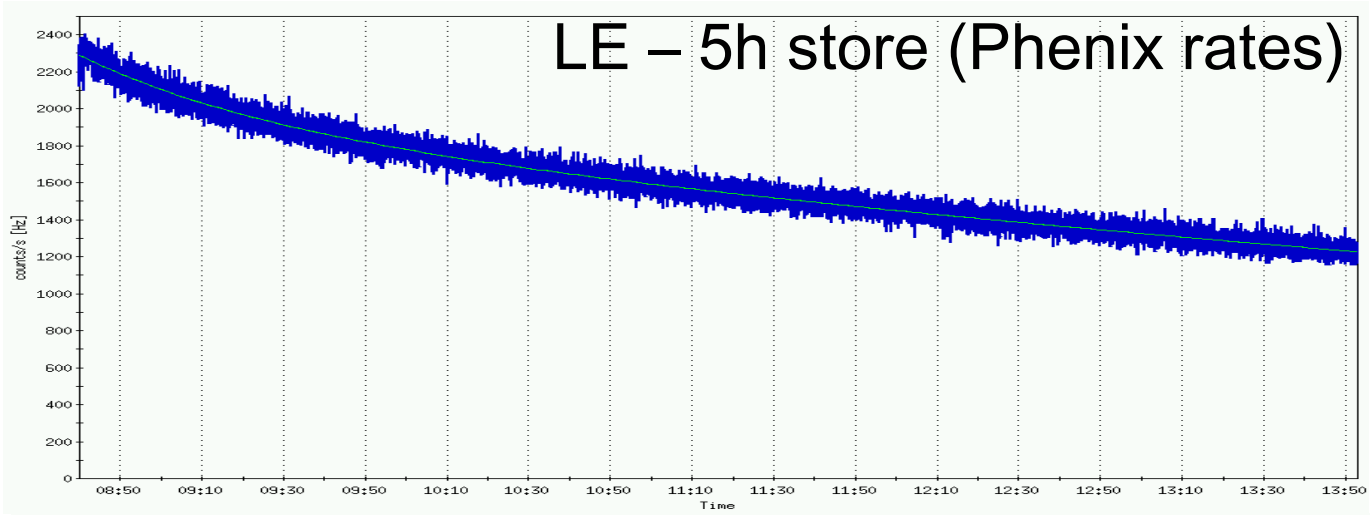


LE Run - week 2 - stores

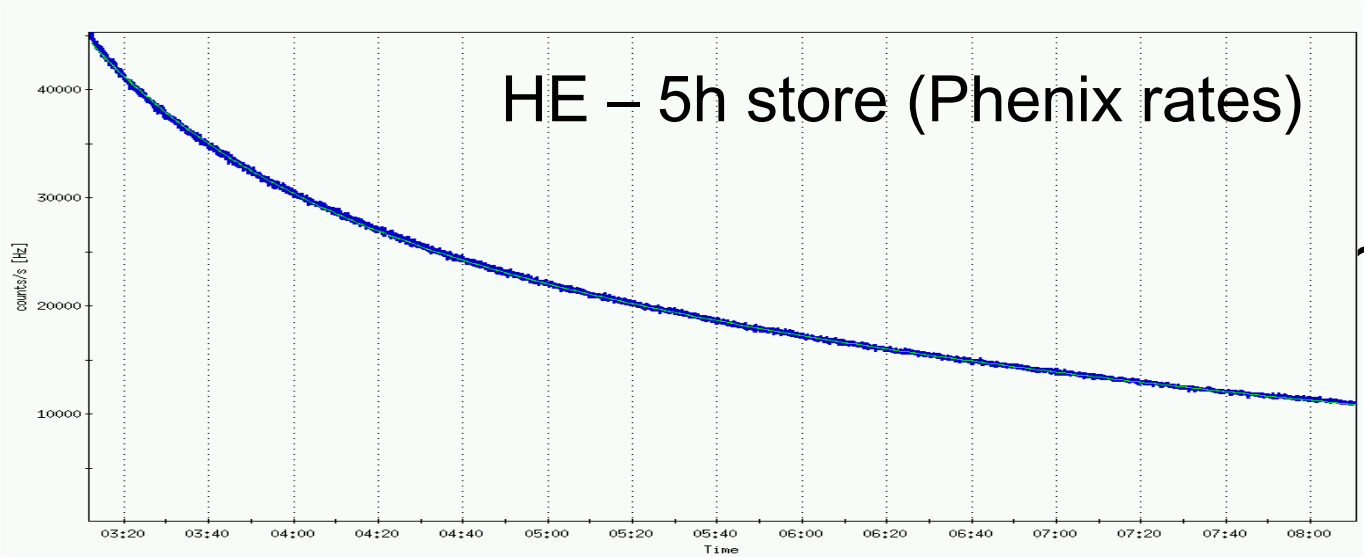




HE and LE luminosity lifetime

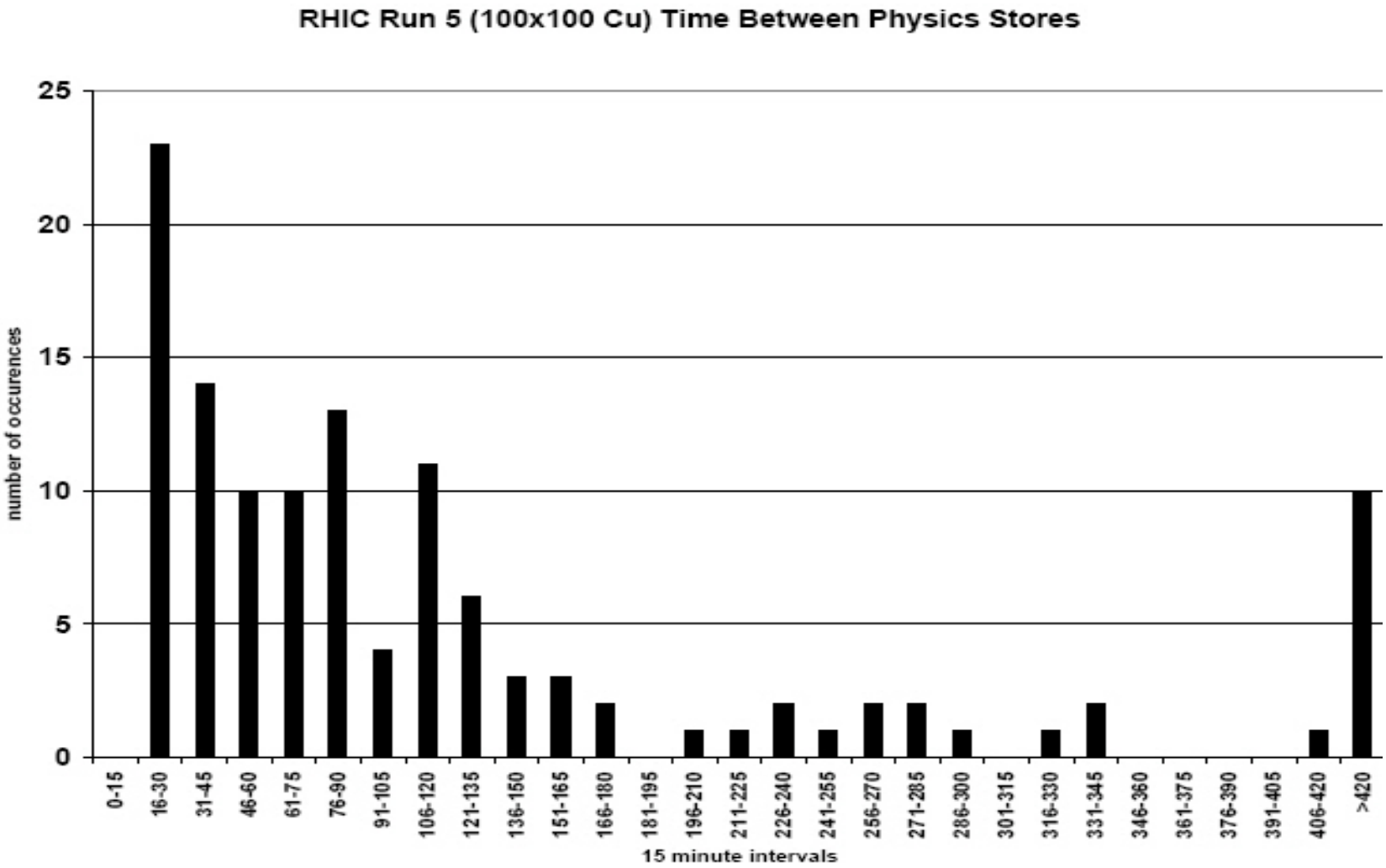


6+ hours

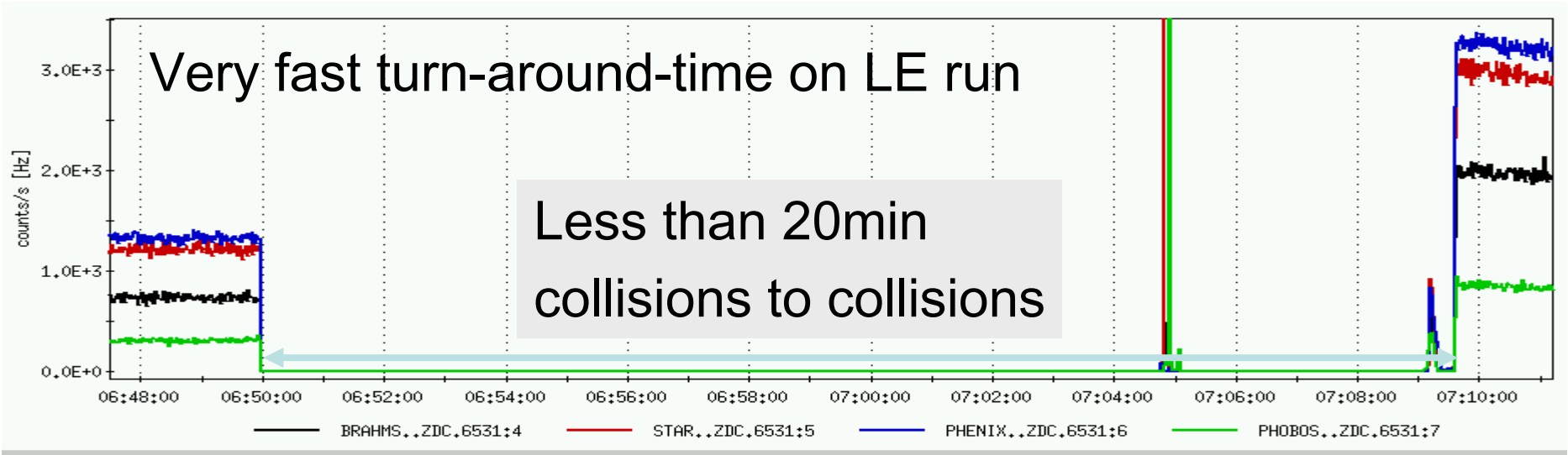


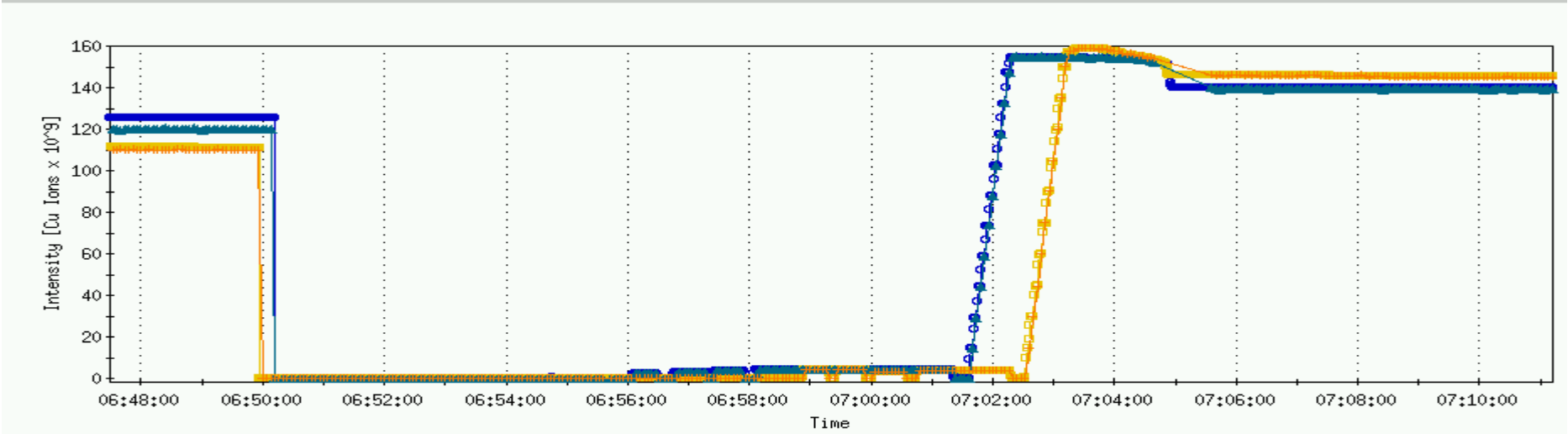
~3-3.5 h

HE: time between stores



LE: store-to-store time





Performance limitations (HE)

Bunch intensity (limit ~5x10^9)

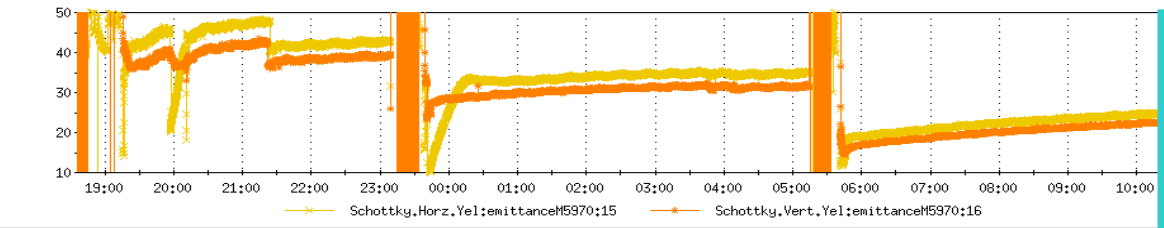
- fast transverse instabilities near transition
- yellow beam lifetime after re-bucketing
- beam-beam (at store)
- IBS

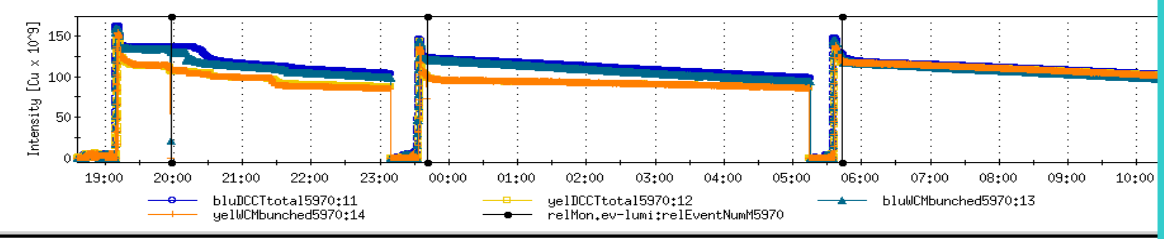
Number of bunches

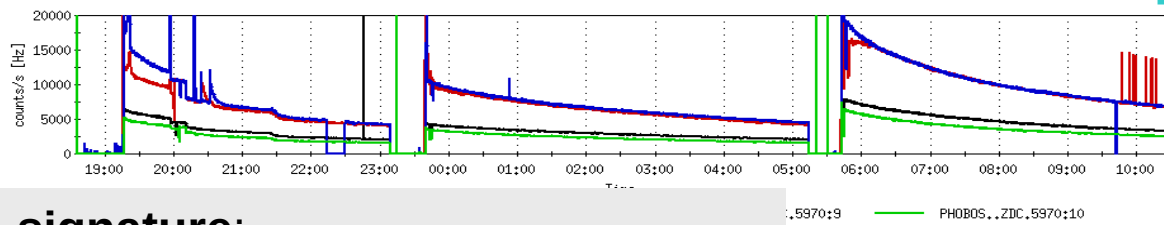
- pressure rise at Phobos (limit: 43x43)
- transition pressure rise at IR4 (limit: 45x45)
- long range beam-beam interactions on the ramp

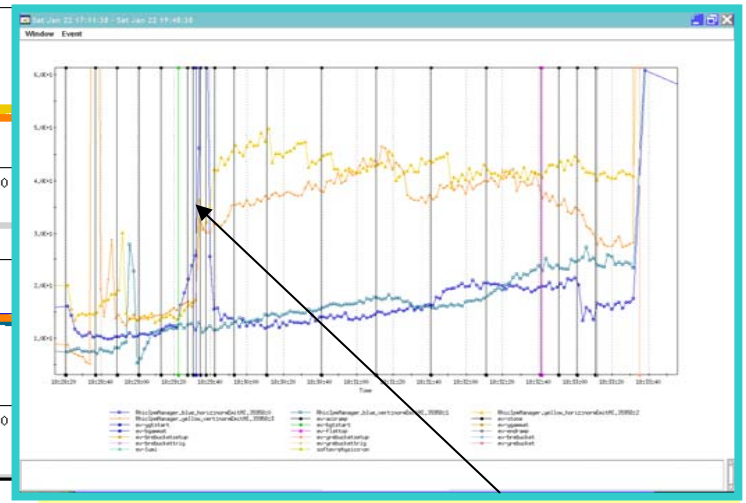
  (limit < 28x28 before improvements)

Fast instability around transition









emittance blow-up ~0.5 sec after transition

signature:

- coherence (0.1-0.8 sec > γt)
- fast loss on DCCT
- 50% emittance blow-up
- no dependence #bunches
- no clear bunch intensity threshold

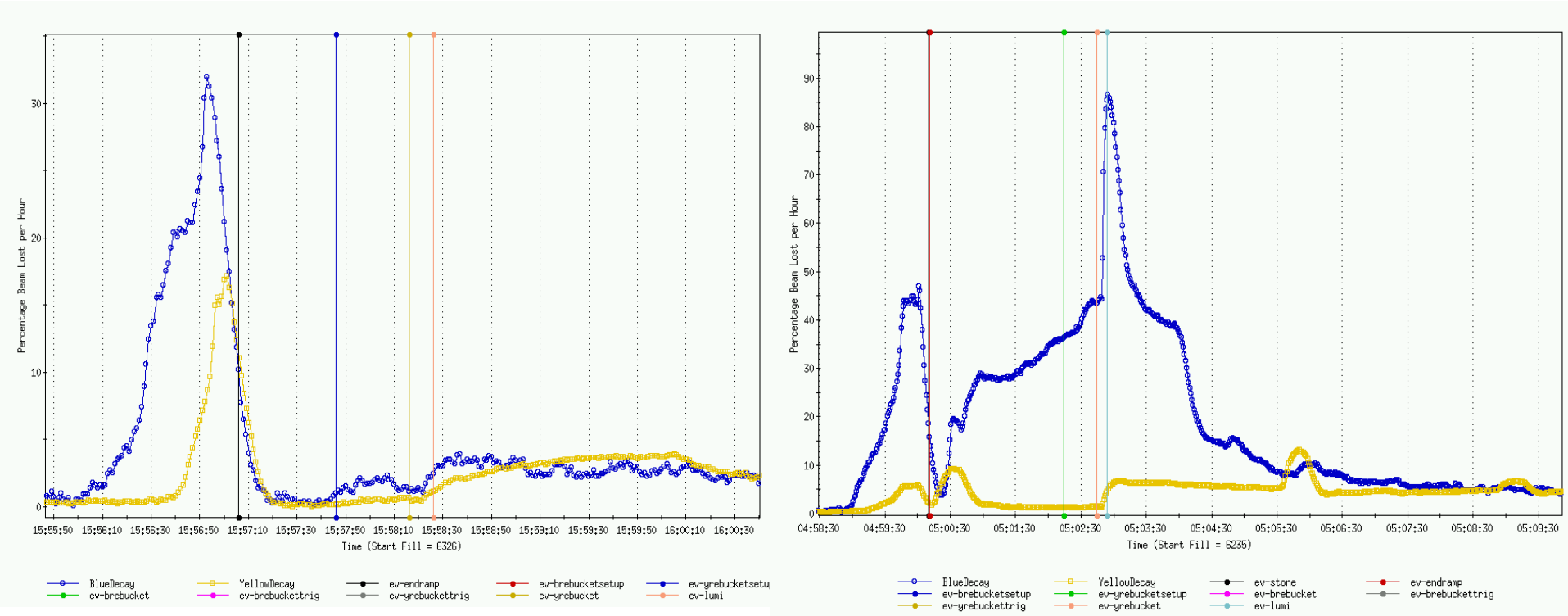
effects:

- bad lifetime
- low rates
- high backgrounds

cures:

- octupoles (not enough)
- zero-crossing of chromaticity moved before γt

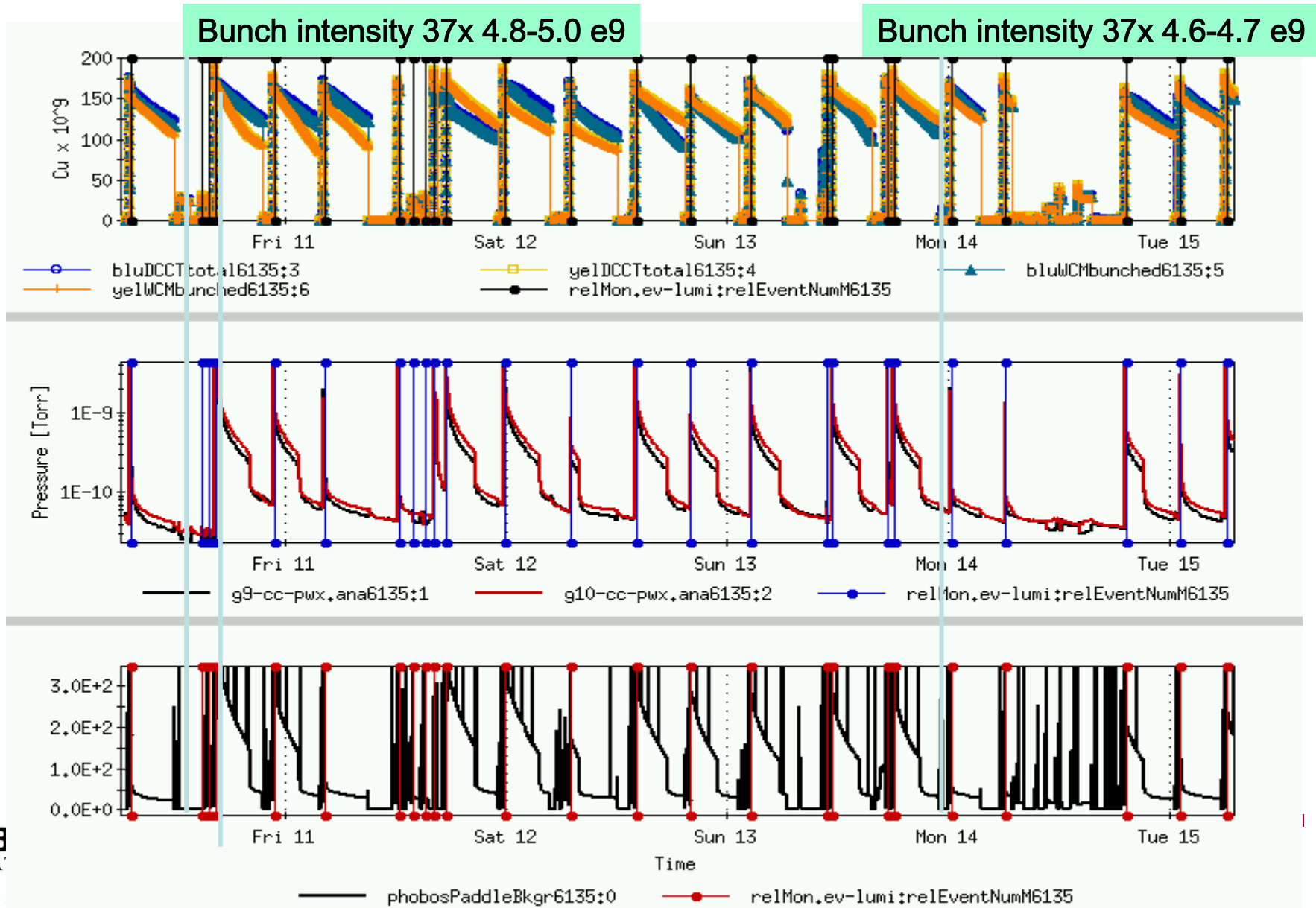
Beam lifetime after re-bucketing



beam decay→ tuning → delay start of physics

- need to keep **chromaticity very close to zero** at and after re-bucketing
- exacerbated by **close orbit shifts** with periodicity of 24 h *(→Vadim's talk)*

Phobos PR and background



Run-5: new developments - 1

- **β^*-squeeze to 0.85m** (Pilat, Malitsky, Ptitsyn, Wittmer)

  *tested run-5 in **Accelerator Physisics Experiments***

  operational run-5, measured β^*=0.89m

  took down separation bump during squeeze

  'usual' initial fight with coupling on the squeeze

  sextupole IR corrections

  online matching capability

- **coupling corrections on the ramp** (Y. Luo)

  *tested during Run-4 & Run-5 **AP-experiments***

  coupling vector amplitude modulation and phase rotation

  operational in Run-5 → success

Run-5 new developments - 2

- **Stochastic cooling tests**

  (M.Brennan,M.Blaskiewicz)

  signal suppression demonstrated
- **Injection into RHIC**

  automated injection set-up

  low-intensity interlock

  auto AGS extraction field correction
- **Configuration control, analysis tools**

  configuration control web page

  FDAView

Run-5 new developments - 3

instrumentation

- BPMS: electronics, beam-based alignment
- IPM re-work→ better
- HF Schottky development (emittance)

vacuum system

200+ m of NEG pipes → validation

power supplies

PS swaps from 60 to 6 in 2 years

RF

Discussed, planned, but ….

- STAR Magnet control from MCR
- ZDC's 'owned' by CAD
- collimation from sequencer
- store configurations (exp magnet polarities)
- **BLAM**

→ re-addressed at the RHIC Retreat last week

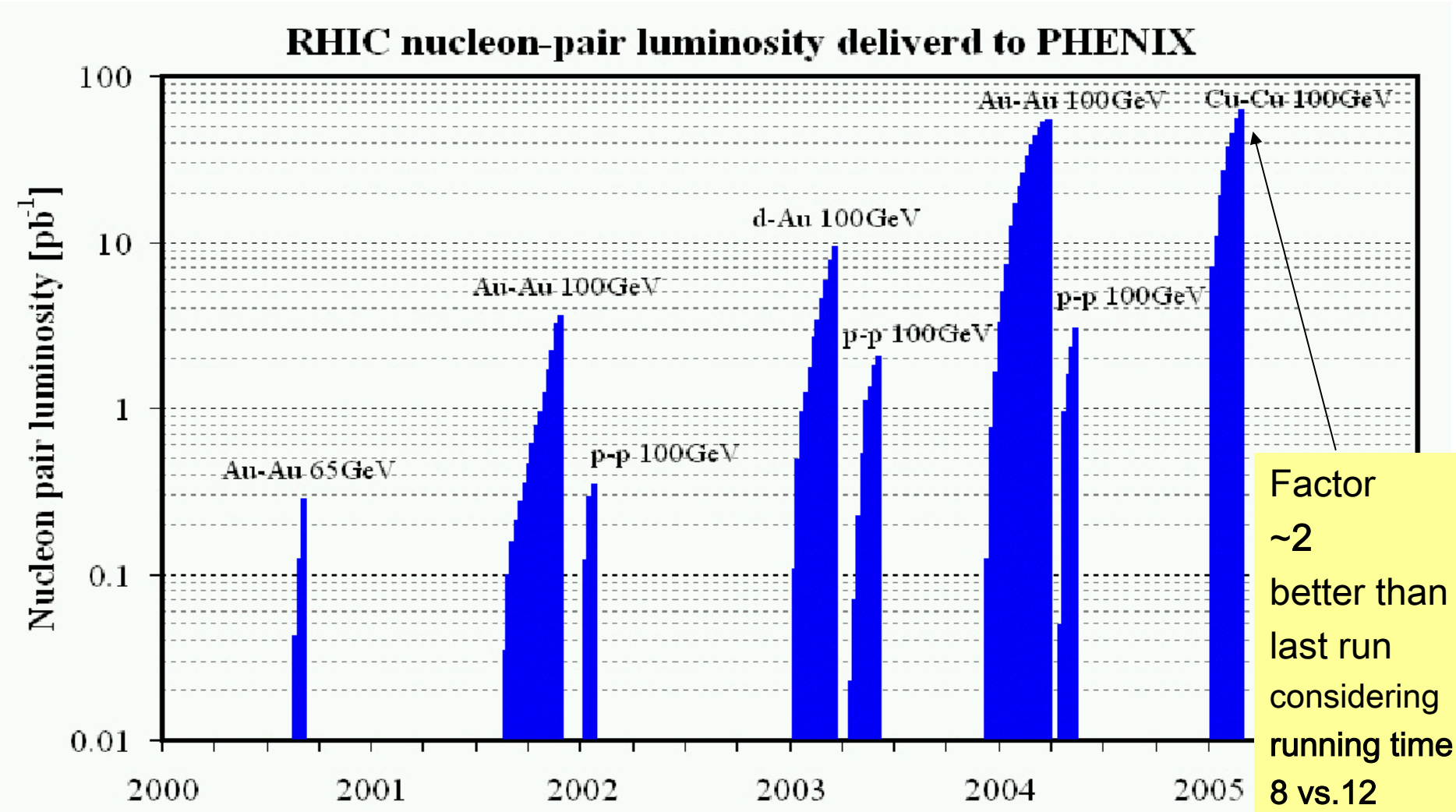
RHIC Retreat 2005

- Shelter Island, June 15-17, 2005

→ Written Summary by the end of June

Wednesday, June 15th - Morning **Opening Session** Overview physics, Run-5 Cu and PP, budget outlook and running scenarios D. Lowenstein	Thursday, June 16th – Morning **Operations** Machine reliability and uptime, procedures, input from OC and operators P. Ingrassia	Friday, June 17th - Morning **Developments, Beam Ex, Model** Model status and improvements, beam experiments results and plans, stochastic cooling, other machine developments V. Ptitsyn
Wednesday, June 15th - Afternoon **Machine-Experiments** Integrated performance, optimization machine and experiments, projections W. Fischer	Thursday, March 16th – Afternoon **Systems** BPM's, Polarimetry, RF, and other critical systems T. Satogata	Friday, June 17th – Afternoon **Closing Session** Guests' talks, Outlook next Hi and PP runs, Retreat summary & deliverables T. Roser

runs overview



Factor ~2 better than last run considering running time 8 vs.12 weeks

conclusion

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The high-energy, low-energy and injection copper run went pretty well.

Thank you to the entire RHIC operations and experimental teams

Beam-beam (store) & IBS

beam-beam at store

→ emittance growth→lumi lifetime

- tolerable nevertheless with Cu and 4 interactions

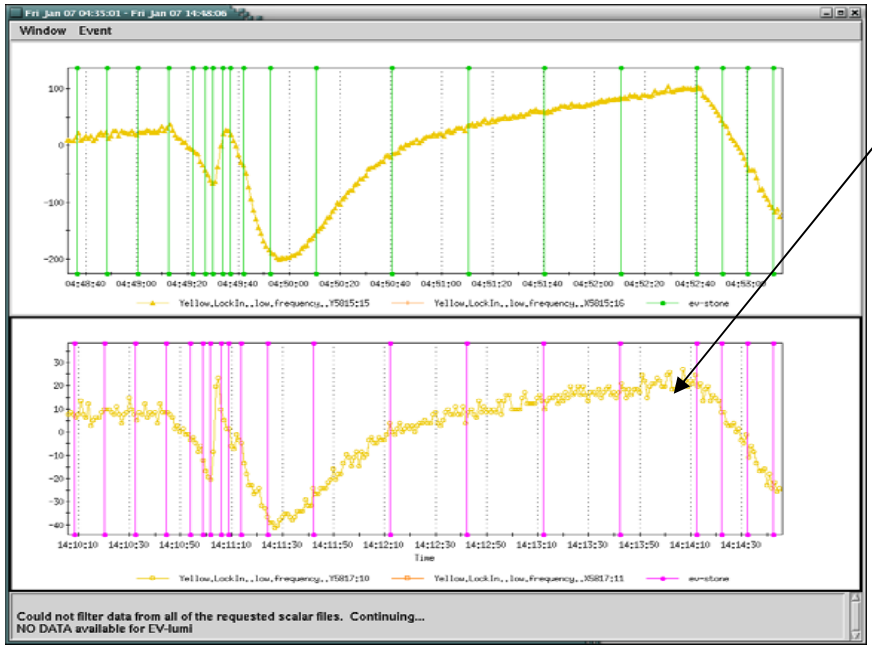
(Δ intensity loss of bunches with 3 and 4 interactions marginal)

- cure: **working point** control (move to 0.73 not necessary)

IBS

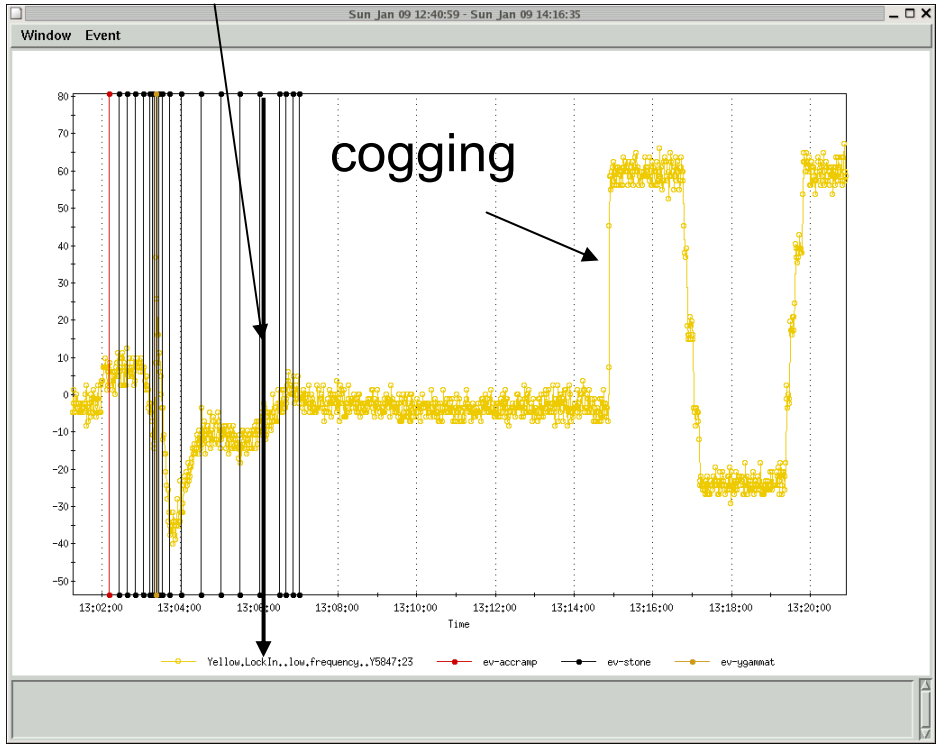
- From pre-run simulations (Fedotov, Wang), IBS less than for Au but significant
- measured and compared during AP experiments
- **operations**: **common cavities**, **continuous gap cleaning**

Long range beam-beam (ramp)



increased ring2ring synchro loop gain

RF dipole



significant losses around transition and the beta squeeze
had to be fixed to allow the initial physics store with 28 bunches

Cure: increase of R-2-R synchro-loop
RF dipole
(vertical separation bumps)

Run-5 integrated lumi (nb-1)

experiment	HE Run-5	HE Run-4	LE Run-5	LE Run-4
Phenix	**15.16**	1.37	**0.50**	0.022
Star	**14.99**	1.27	**0.46**	0.021
Brahms	**6.15**	0.56	**0.29**	0.012
Phobos	**5.67**	0.54	**0.24**	0.012