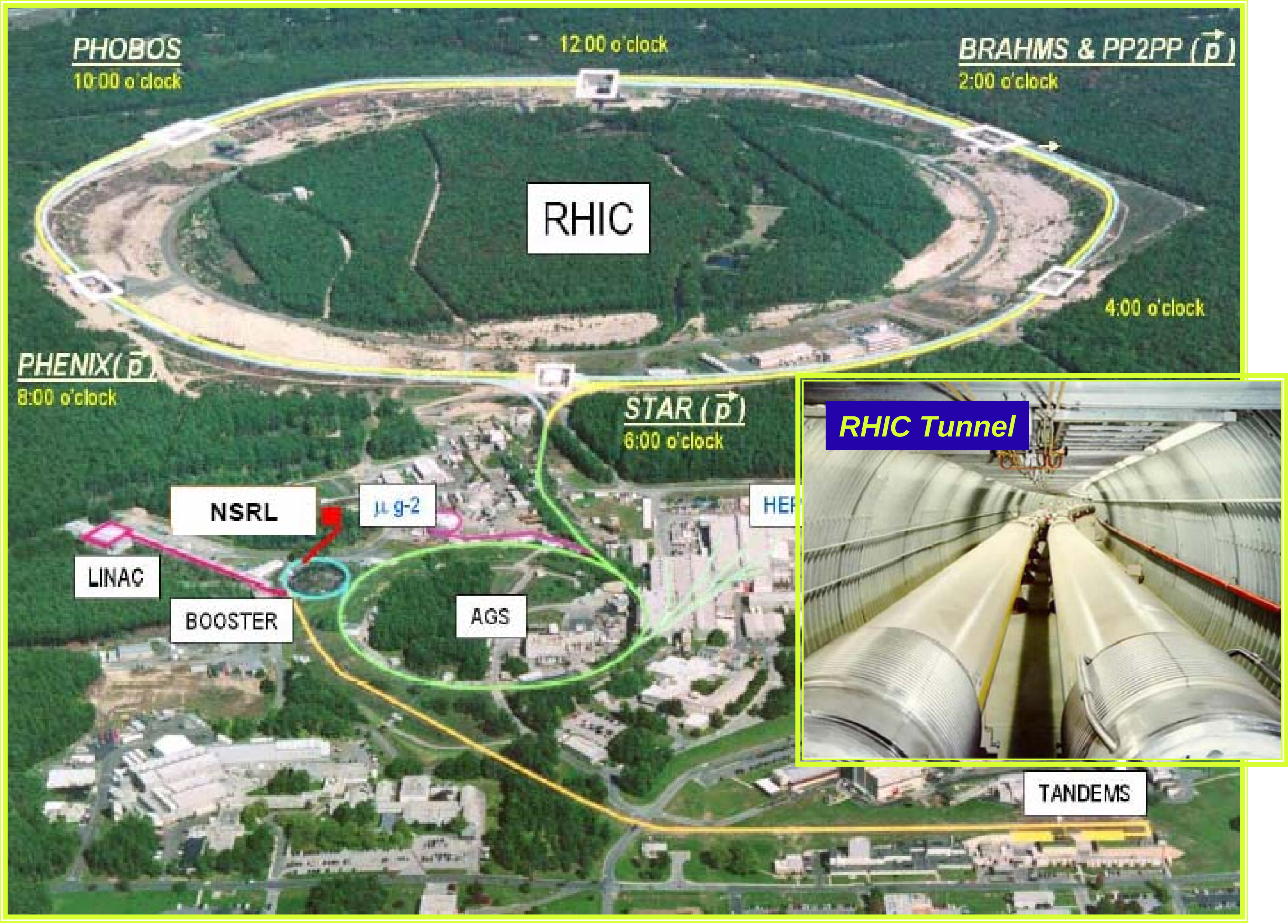
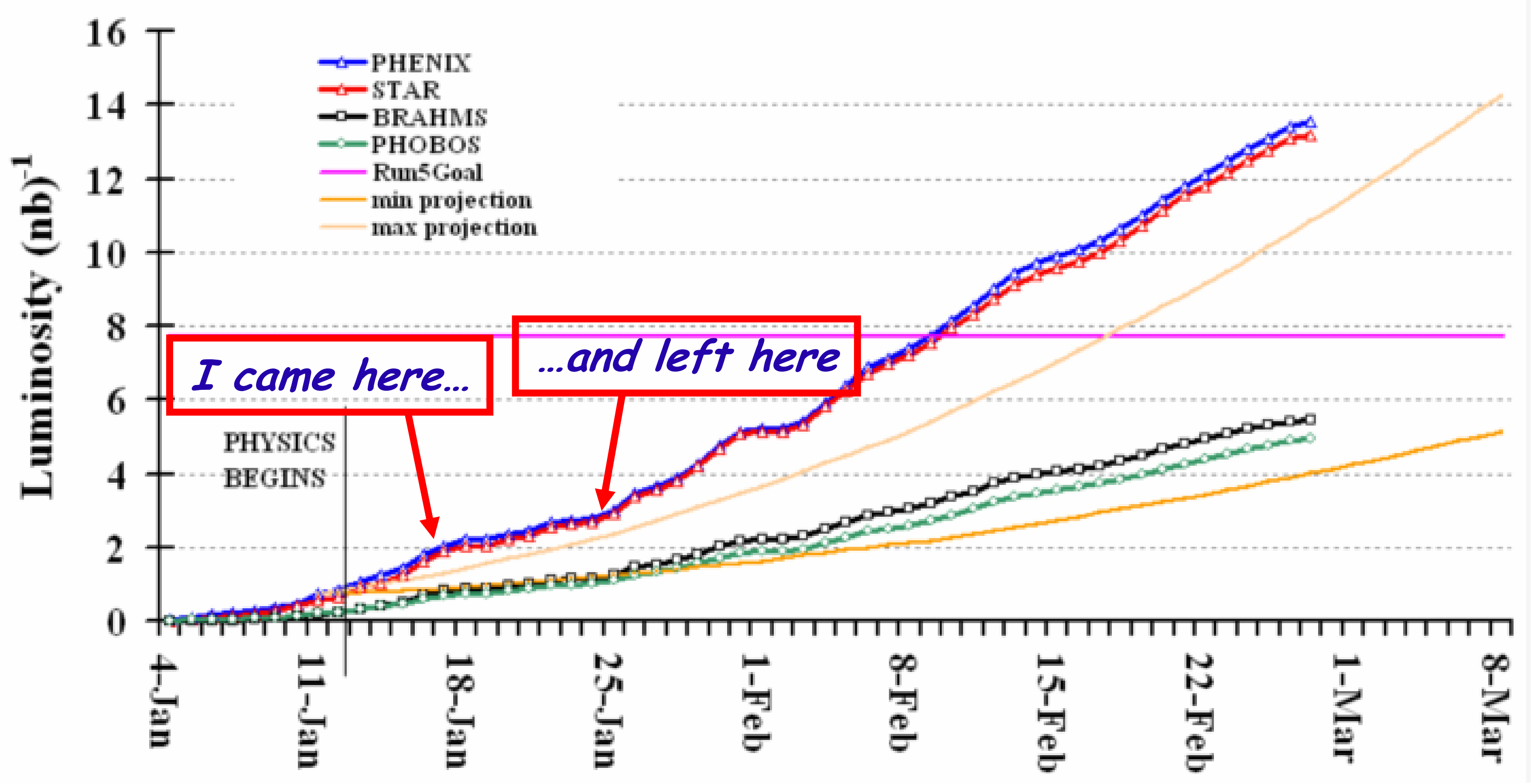
Review of RHIC visit, 17-25 Jan. 2005

- RHIC overview
- RHIC collimation system
- Benchmarking of ICOSIM
- Conclusions


PHOBOS
10:00 o'clock
12:00 o'clock
BRAHMS & PP2PP ($\vec{p}$)
2:00 o'clock
RHIC
4:00 o'clock
PHENIX ($\vec{p}$)
8:00 o'clock
STAR ($\vec{p}$)
6:00 o'clock
RHIC Tunnel
NSRL
μ g-2
LINAC
BOOSTER
AGS
TANDEMS

The Relativistic Heavy Ion Collider Run-5
Copper-Copper Operation 2004/05



… and the most violent blizzard recorded in Long Island during the last decade took place on January 22-23 !

RHIC has many similarities with LHC

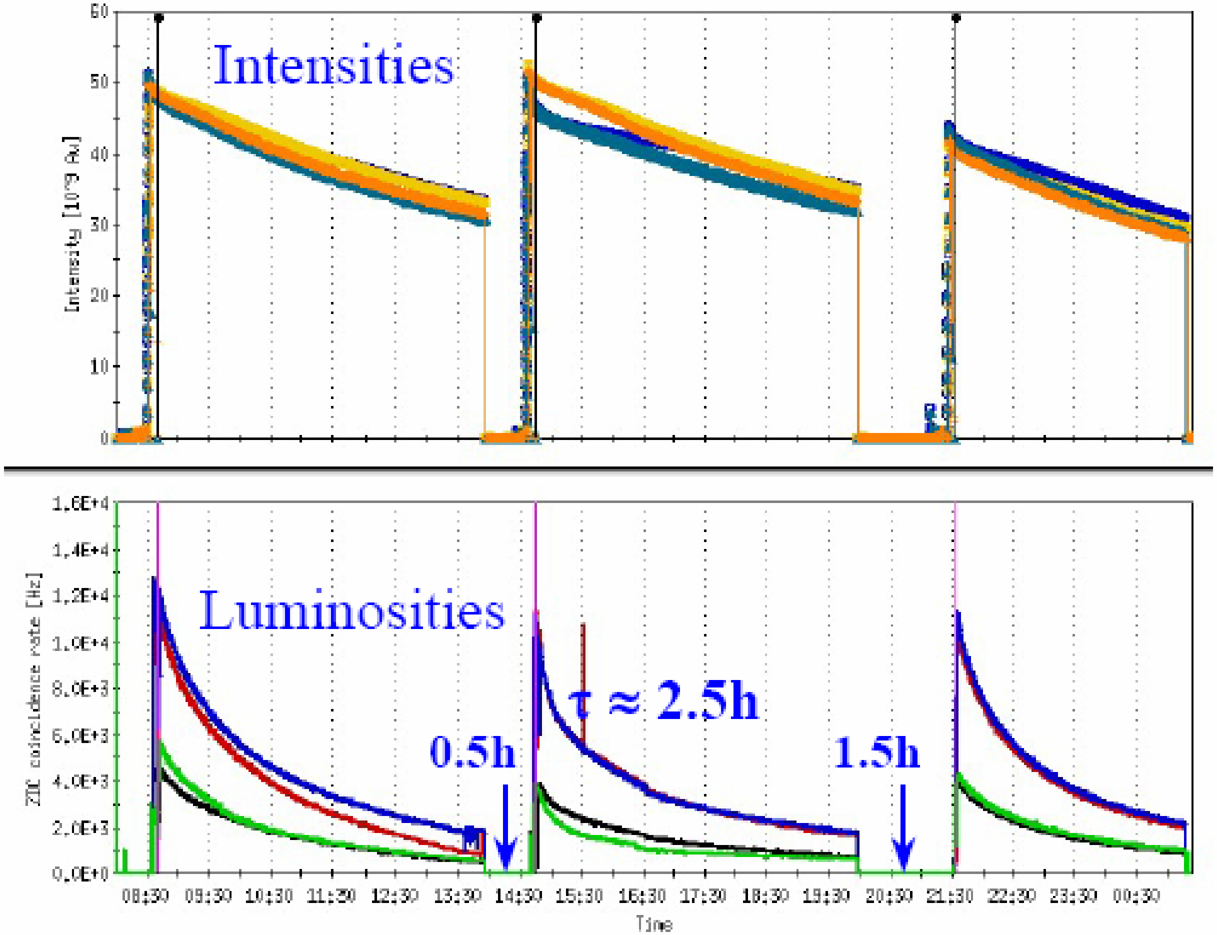
- Two intersecting superconducting rings
- Complex injector chain
- Operation with protons and heavy ions

But also differences

- The RHIC rings have magnets in separate cryostates, combiner/splitter magnets around IP's are only common magnets
- RHIC is not in a deep tunnel, but just covered with soil
  → radiation issues
- Purpose of collimation is mainly reduction of experimental backgrounds

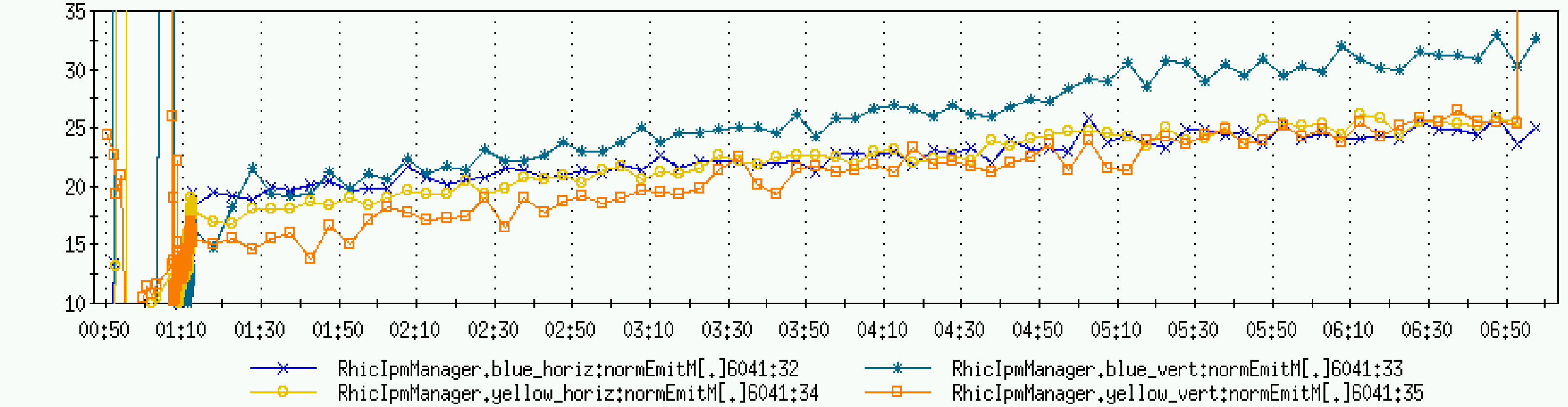
	Circumference	Energy / nucleon	Stored energy / beam	rms Emittance	chamber width (arc)
	m	GeV/u	MJ	μm (norm,)	mm
RHIC p	3834	200	0.2	2.5-10	78
RHIC Au		100	0.2		
RHIC Cu		100	0.2		
LHC p	26659	7000	362	3.8	44
LHC Pb		2760	3.8	1.5	

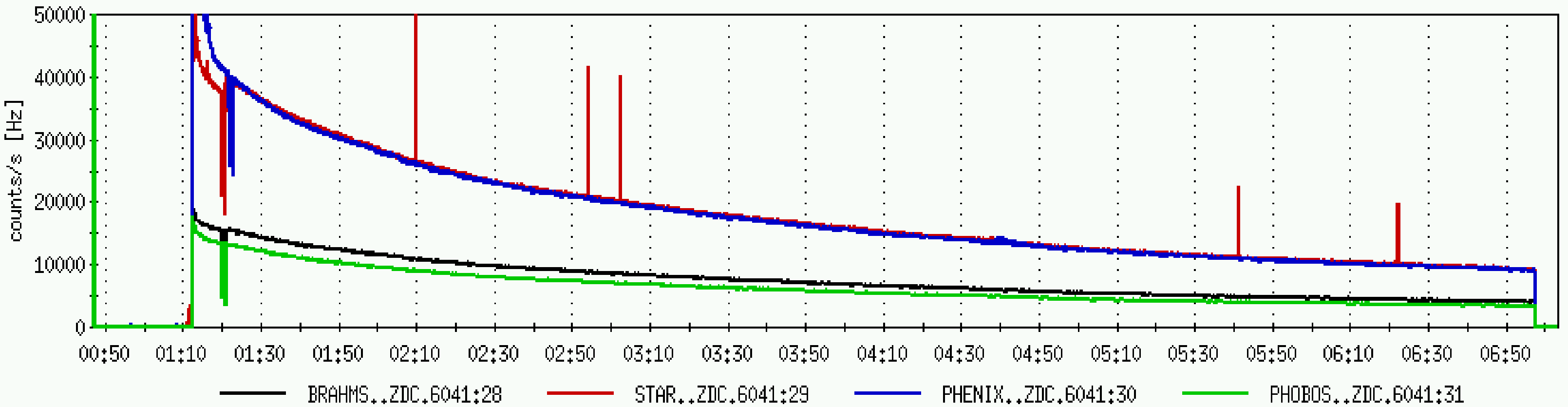
Luminosity Limit – Intra-Beam Scattering (IBS)

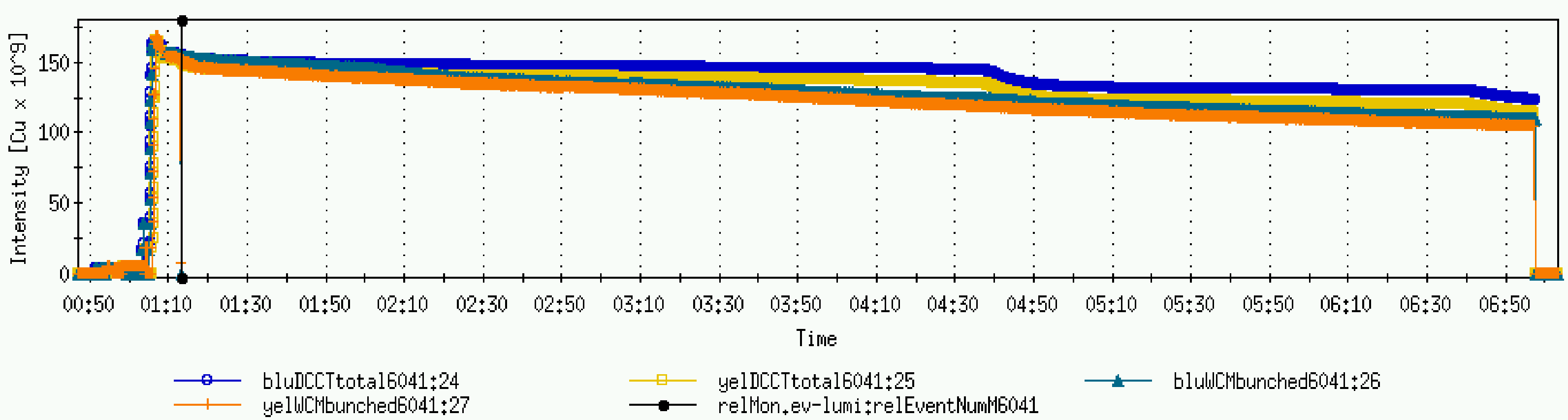


- Debunching requires continuous gap cleaning (tune meter)
- Luminosity lifetime requires frequent refills
- Ultimately need cooling at full energy

BROOKHAVEN NATIONAL LABORATORY


35
30
25
20
15
10
00:50 01:10 01:30 01:50 02:10 02:30 02:50 03:10 03:30 03:50 04:10 04:30 04:50 05:10 05:30 05:50 06:10 06:30 06:50
RhicIpmManager.blue_horiz:normEmitM[.]6041:32
RhicIpmManager.blue_vert:normEmitM[.]6041:33
RhicIpmManager.yellow_horiz:normEmitM[.]6041:34
RhicIpmManager.yellow_vert:normEmitM[.]6041:35

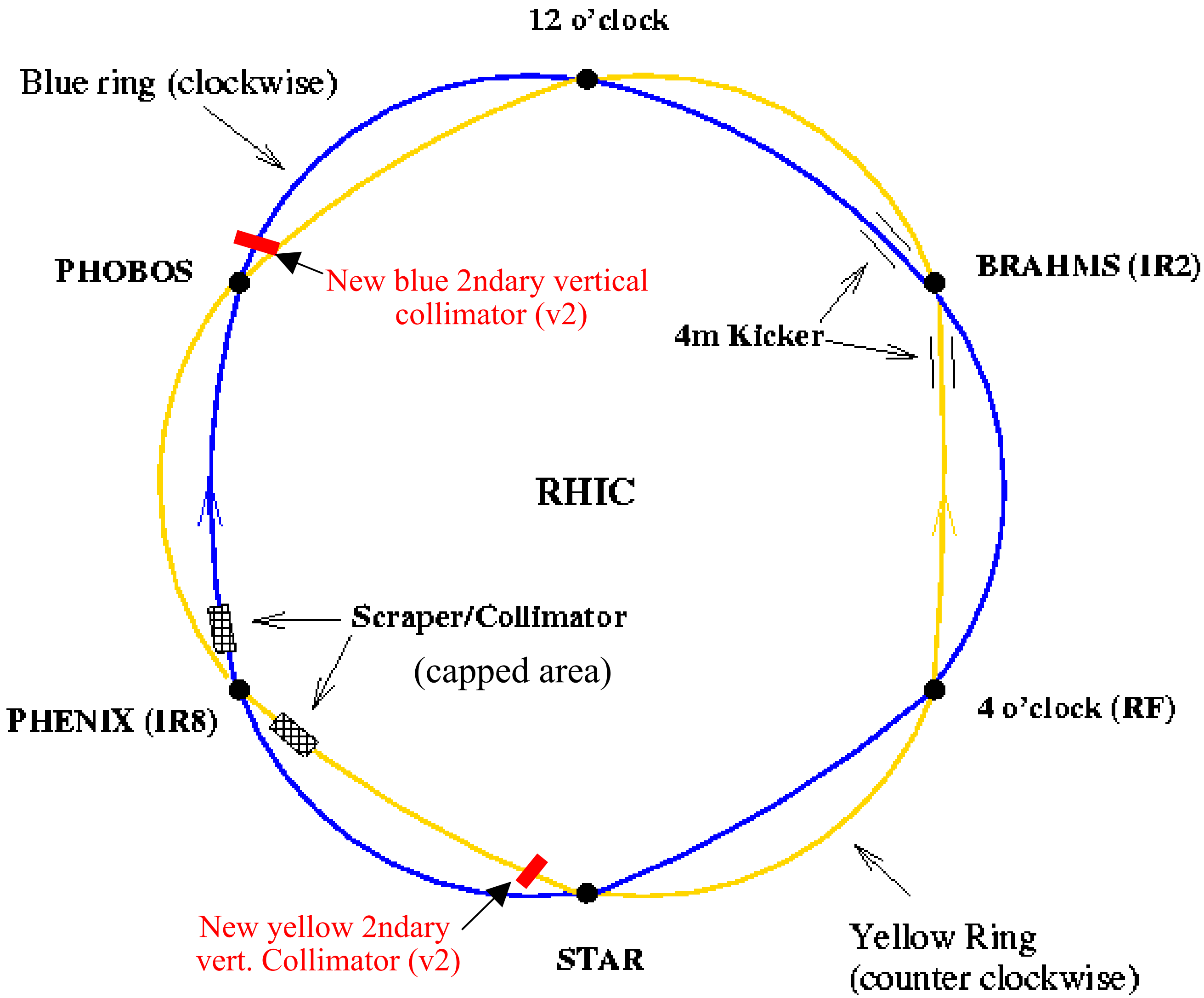

counts/s [Hz]
50000
40000
30000
20000
10000
0
00:50 01:10 01:30 01:50 02:10 02:30 02:50 03:10 03:30 03:50 04:10 04:30 04:50 05:10 05:30 05:50 06:10 06:30 06:50
BRAHMS..ZDC.6041:28
STAR..ZDC.6041:29
PHENIX..ZDC.6041:30
PHOBOS..ZDC.6041:31


Intensity [Cu x 10^9]
150
100
50
0
00:50 01:10 01:30 01:50 02:10 02:30 02:50 03:10 03:30 03:50 04:10 04:30 04:50 05:10 05:30 05:50 06:10 06:30 06:50
Time
bluDCCTtotal6041:24
yelDCCTtotal6041:25
bluWCMbunched6041:26
yelWCMbunched6041:27
relMon.ev-lumi:relEventNumM6041

RHIC Collimator Configuration

- RHIC was originally built with a 1-stage collimation system only:
  - 1 dual plane h/v scraper with 45 cm copper jaws, linear motion in both planes, skew motion only in horizontal
  - 1 bent crystal collimator for studies in 1 ring (yellow) only
- The system was upgraded after the 2003 run because of high experimental backgrounds and gap cleaning demands. Crystal approach proved non sufficient.

RHIC overview: collimation system 2004 and upgrade



2000-2003:
1-stage system including bent crystal in 1 ring

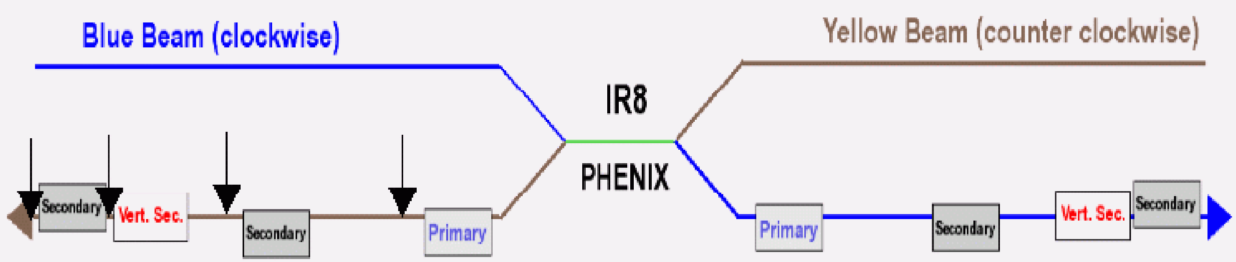
2004:
Traditional 2-stage system with 2 horizontal and 1 vertical secondary collimators

2005:
Traditional 2-stage system with 2 horizontal and 2 vertical secondary collimators

Collimator Section Layout

In the shutdown 2003-2004 the collimation system was upgraded to a conventional 2-stage system including new individual secondary collimators for both planes. The new system was first used in the run 2004 for both, Au and protons.

New Collimation System



Primary Collimators are Horizontal and Vertical

Grey Secondary Collimators are Horizontal

White Collimators are Vertical and will not be functional on Day 1

They are to catch the scattered particles from the Primary collimator

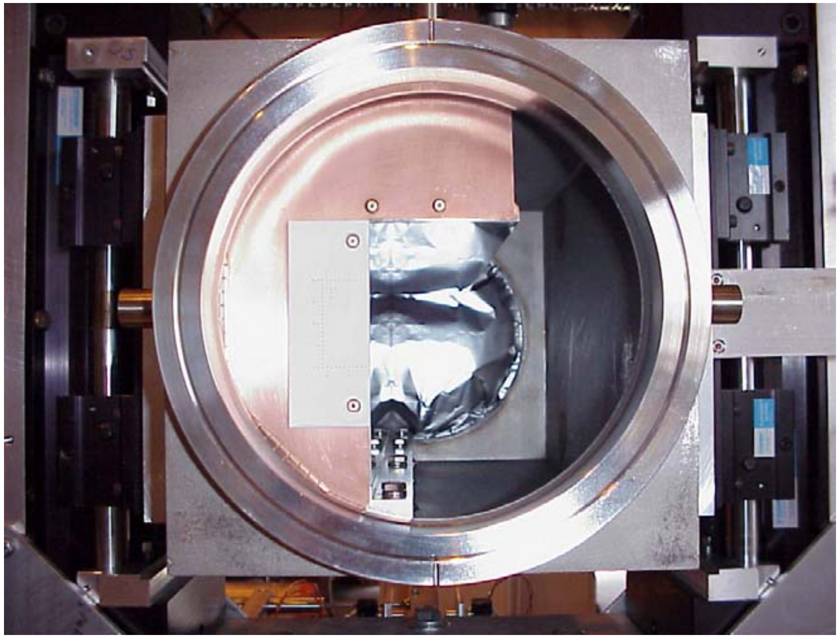
The positions in [m] from the IR are:

primary	41.2
1. secondary H	51.1
secondary V	57.3
2. secondary H	58.3

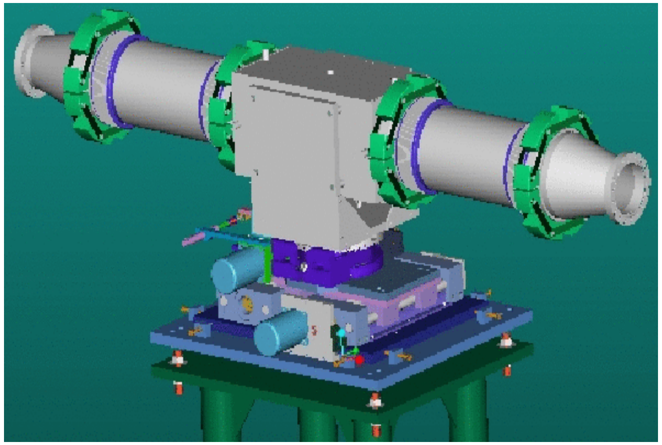
position PD 1m downstream of collimator (or as much downstream as possible)

Collimator Design

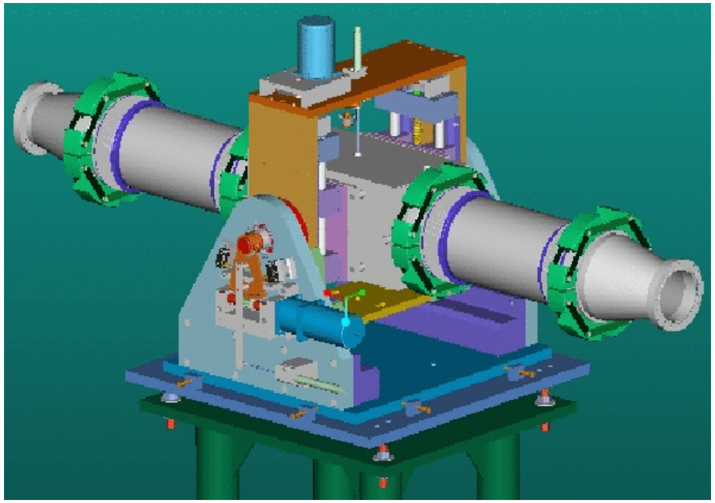
45 cm copper jaws
One side only
Rotatable, positioning: few μm



cross-section of the primary collimator (dual plane)



H



V

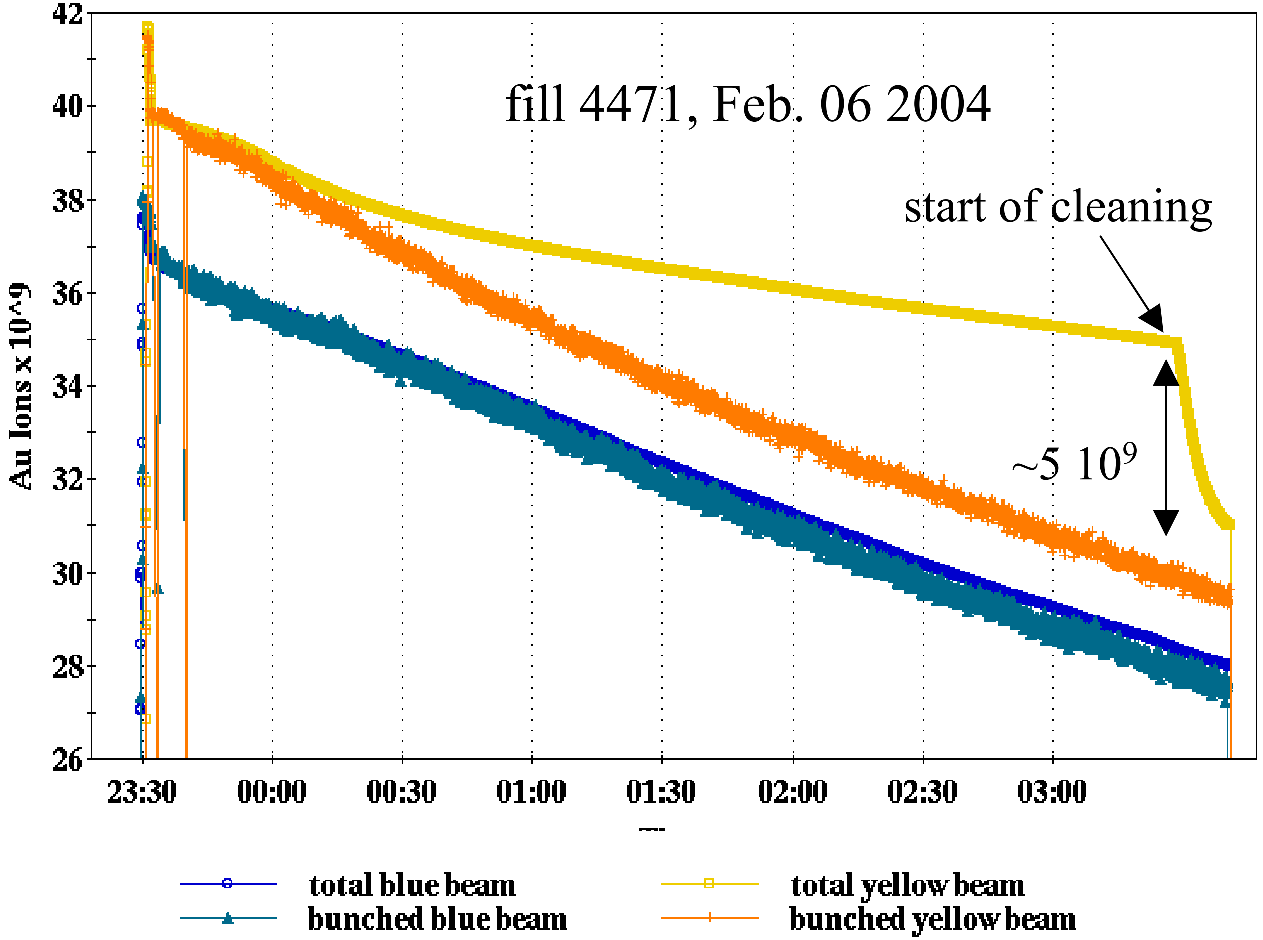
Loss Limitations

- Operational limit: keep allowable loss budget (radiation safety), monitored hour by hour
- Quench limit:
  - magnet quenches due to accidental local losses during ramp/store => BLMs
  - magnet quenches at beam dump due to debunched beam => gap cleaning
- Soil activation (not under radiation protection), depends on integrated yearly losses
- Experimental backgrounds: need ‘clean’ beams to allow good signal/noise ratio in experiments and keep false trigger rate small (dead time)

Gap Cleaning: Motivation and Method

- gap cleaning is necessary due to the extensive debunching of HI beams (quenching risk)
- method:
  - debunched beam is excited transversely (continuously during the store: 1Hz) using damping kickers
  - the collimation system absorbs the large amplitude particles (in addition to halo)
- debunched is almost completely lost at collimators, efficiency relies on collimator performance to avoid increase of exp. backgrounds

Cleaning ON vs. cleaning OFF:

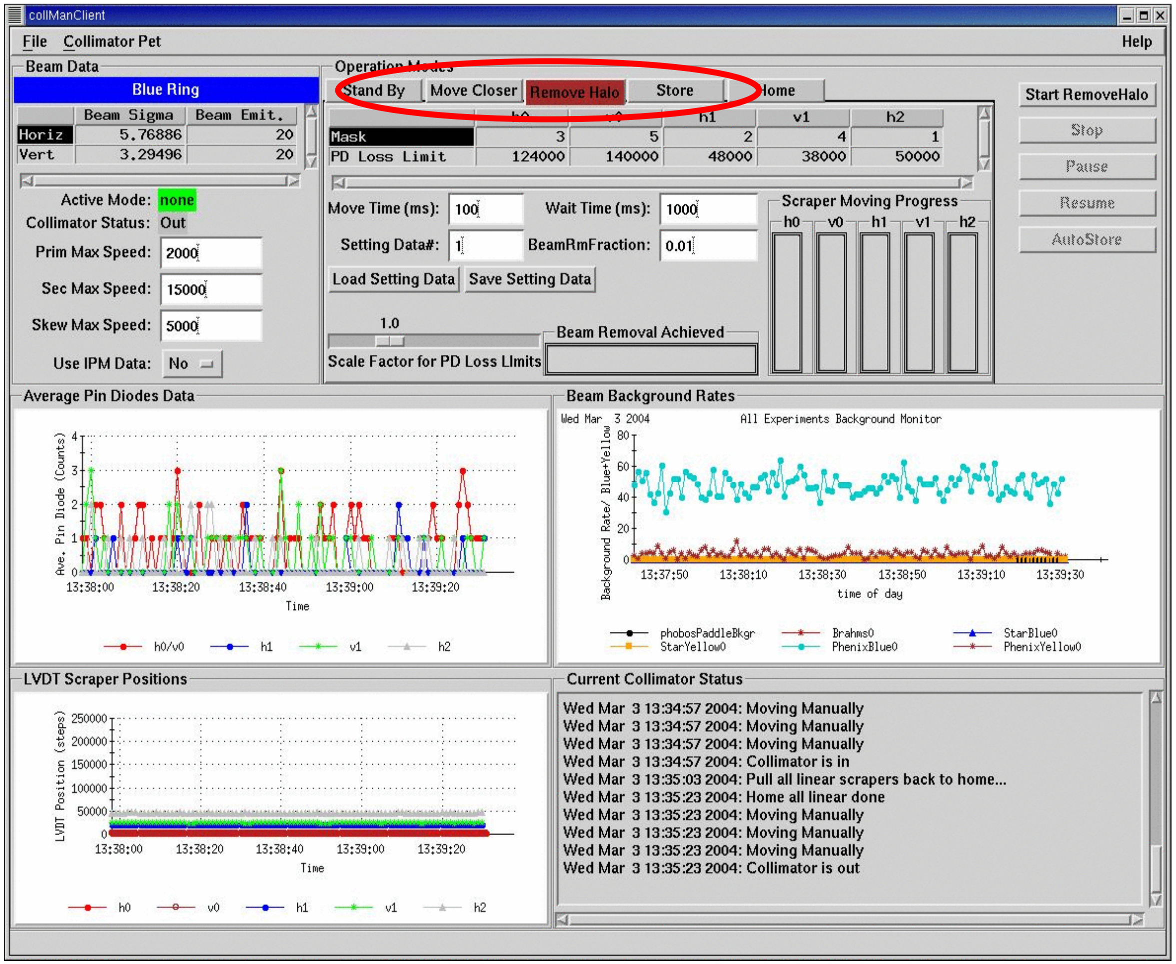


56 x 56

yellow:
cleaning off, started around 3:30 to allow clean beam dump

blue:
cleaning on, debunched beam is continuously excited and absorbed by collimators

Automatic Steering Algorithm

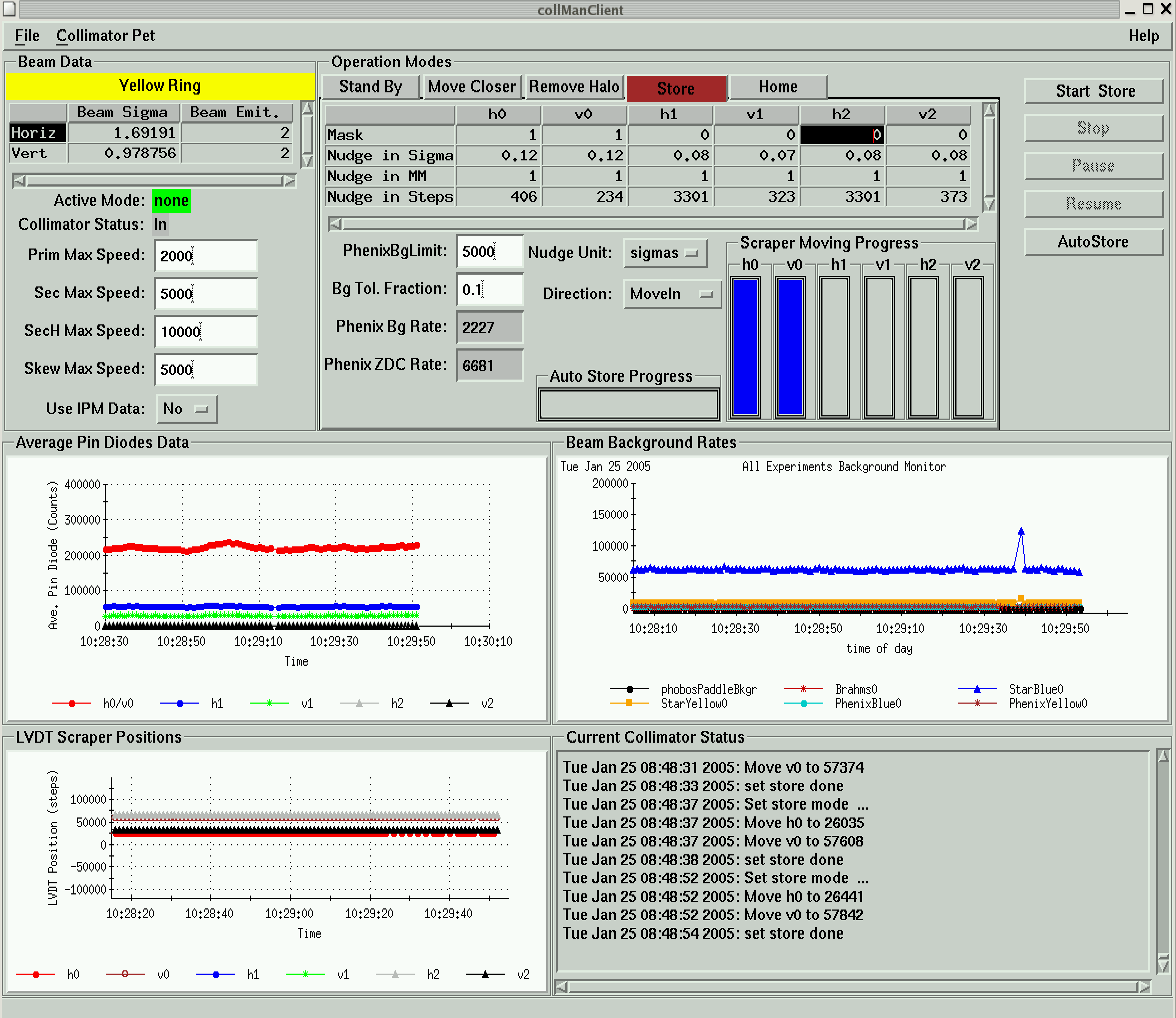


RHIC has 5 jaws per ring, most allow both, linear motion and angular motion (to parallelize with beam). Potentially time consuming!

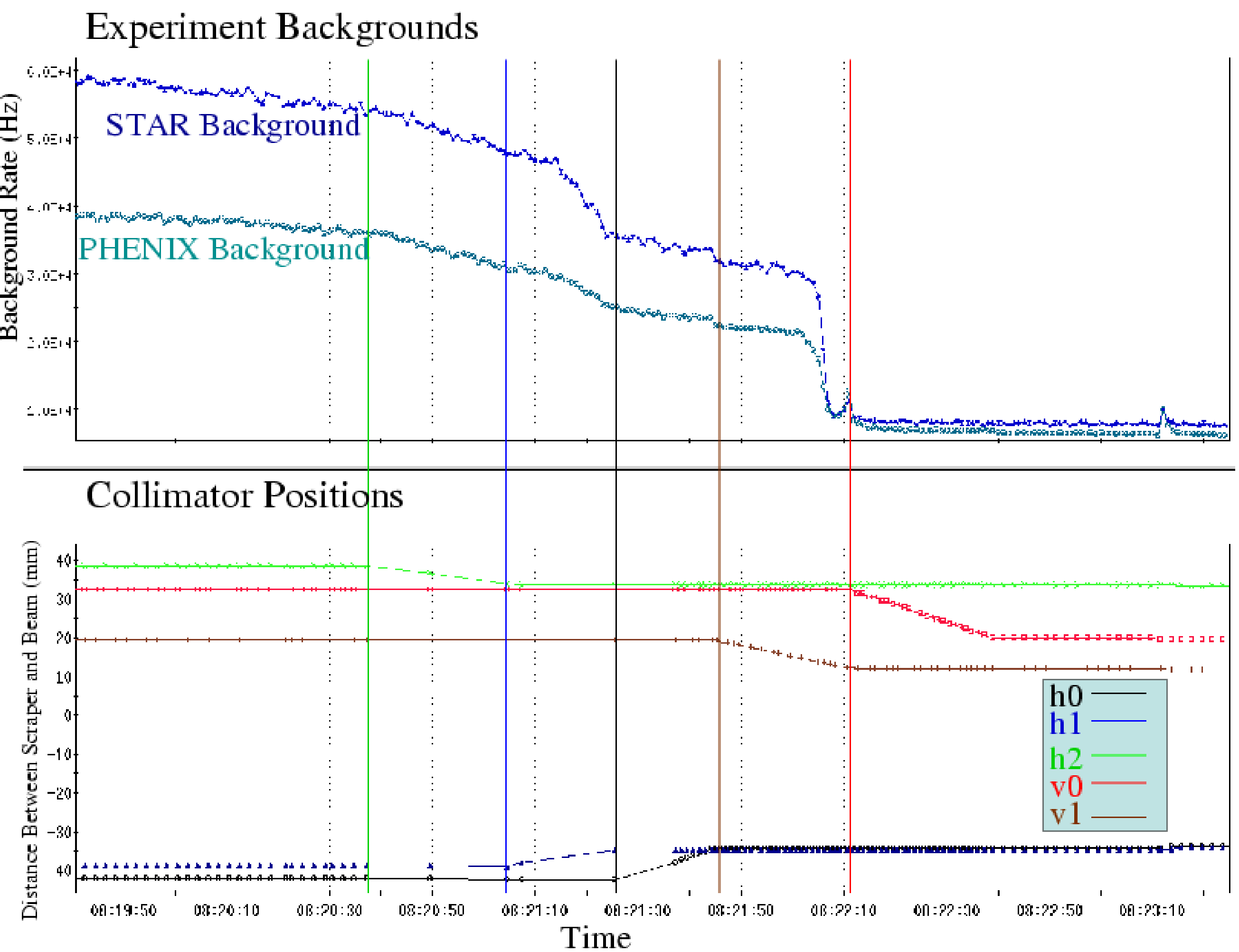
=> 18 degrees of freedom
(+ 4 more next run)

Requires automation (3 steps):

1. Move to **STDBY** position (based on BPM readings)
2. **Move Closer** to beam (based on loss monitor feedback, serial)
3. **Remove Halo/Store** (based on lattice functions, parallel)


collManClient
File
Collimator Pet
Help
Beam Data
Yellow Ring
Beam Sigma
Beam Emit.
Horiz 1.69191 2
Vert 0.978756 2
Active Mode: none
Collimator Status: In
Prim Max Speed: 2000
Sec Max Speed: 5000
SecH Max Speed: 10000
Skew Max Speed: 5000
Use IPM Data: No
Operation Modes
Stand By
Move Closer
Remove Halo
Store
Home
h0 v0 h1 v1 h2 v2
Mask 1 1 0 0 0 0
Nudge in Sigma 0.12 0.12 0.08 0.07 0.08 0.08
Nudge in MM 1 1 1 1 1 1
Nudge in Steps 406 234 3301 323 3301 373
PhenixBgLimit: 5000
Bg Tol. Fraction: 0.1
Phenix Bg Rate: 2227
Phenix ZDC Rate: 6681
Nudge Unit: sigmas
Direction: MoveIn
Auto Store Progress
Scraper Moving Progress
h0 v0 h1 v1 h2 v2
Start Store
Stop
Pause
Resume
AutoStore
Average Pin Diodes Data
Ave. Pin Diode (Counts)
400000
300000
200000
100000
0
10:28:30 10:28:50 10:29:10 10:29:30 10:29:50 10:30:10
Time
h0/v0 h1 v1 h2 v2
Beam Background Rates
Tue Jan 25 2005
All Experiments Background Monitor
200000
150000
100000
50000
0
10:28:10 10:28:30 10:28:50 10:29:10 10:29:30 10:29:50
time of day
phobosPaddleBkgr
Brahms0
StarBlue0
StarYellow0
PhenixBlue0
PhenixYellow0
LVDT Scraper Positions
LVDT Position (steps)
100000
50000
0
-50000
-100000
10:28:20 10:28:40 10:29:00 10:29:20 10:29:40
Time
h0 v0 h1 v1 h2 v2
Current Collimator Status
Tue Jan 25 08:48:31 2005: Move v0 to 57374
Tue Jan 25 08:48:33 2005: set store done
Tue Jan 25 08:48:37 2005: Set store mode ...
Tue Jan 25 08:48:37 2005: Move h0 to 26035
Tue Jan 25 08:48:37 2005: Move v0 to 57608
Tue Jan 25 08:48:38 2005: set store done
Tue Jan 25 08:48:52 2005: Set store mode ...
Tue Jan 25 08:48:52 2005: Move h0 to 26441
Tue Jan 25 08:48:52 2005: Move v0 to 57842
Tue Jan 25 08:48:54 2005: set store done

Collimation during Fill 4854 (Au) in the blue ring



Serial collimator steering (mode: Move Closer), following parallel mode does not improve backgrounds.

Vertical lines denote when each collimator moves. Background improvement approx. x6.

Note: secondary vertical collimator quite efficient.

Benchmarking of ICOSIM with RHIC data

- ***Concept:***
  compare loss maps measured with BLM's with those computed from ICOSIM

- ***RHIC has ion-chamber BLM's all around the rings.***
  Normally they cannot distinguish between losses in BLUE and YELLOW ring.

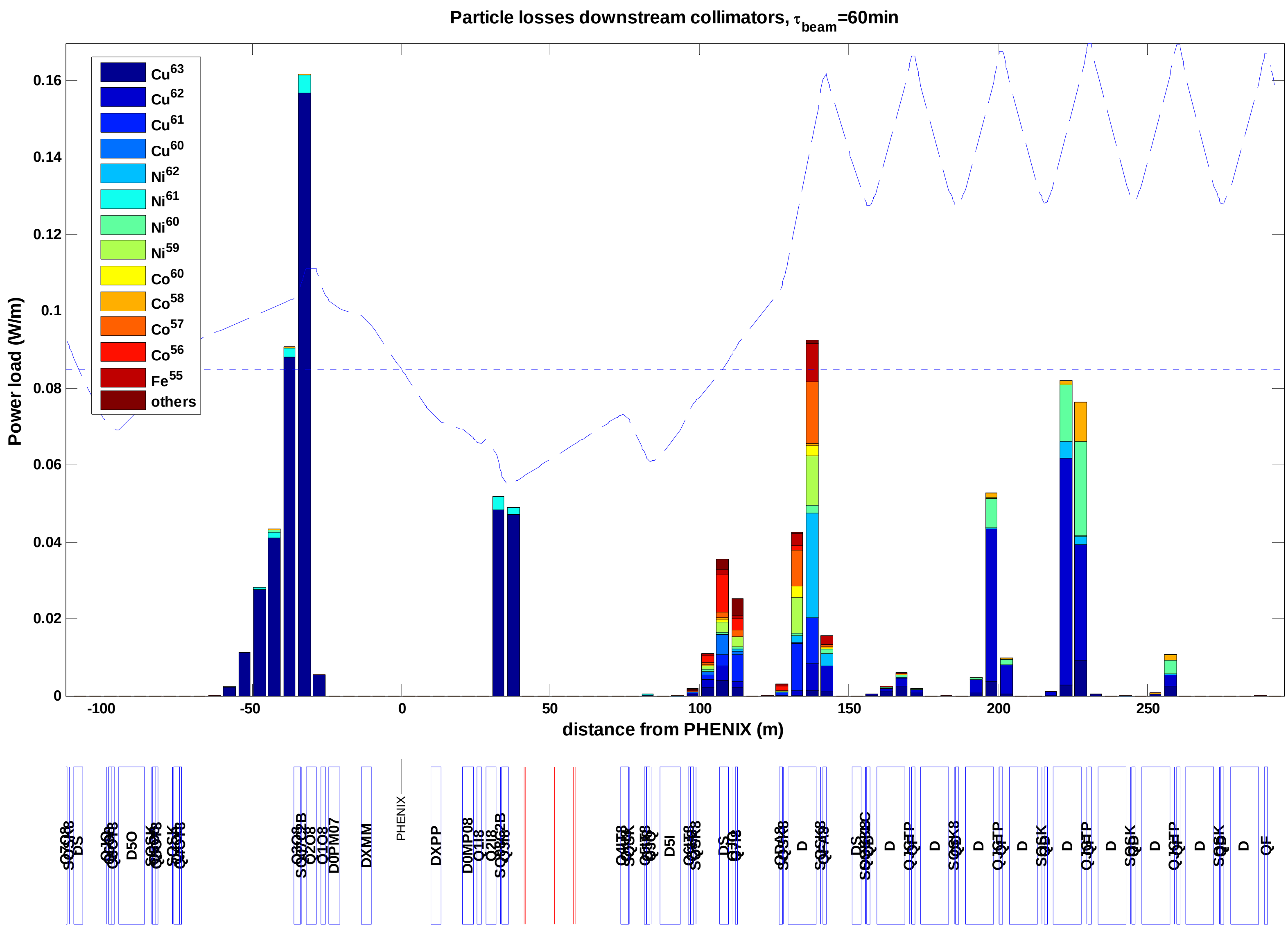
- ***During normal store BLM's on cryostats see nothing until something goes wrong.***

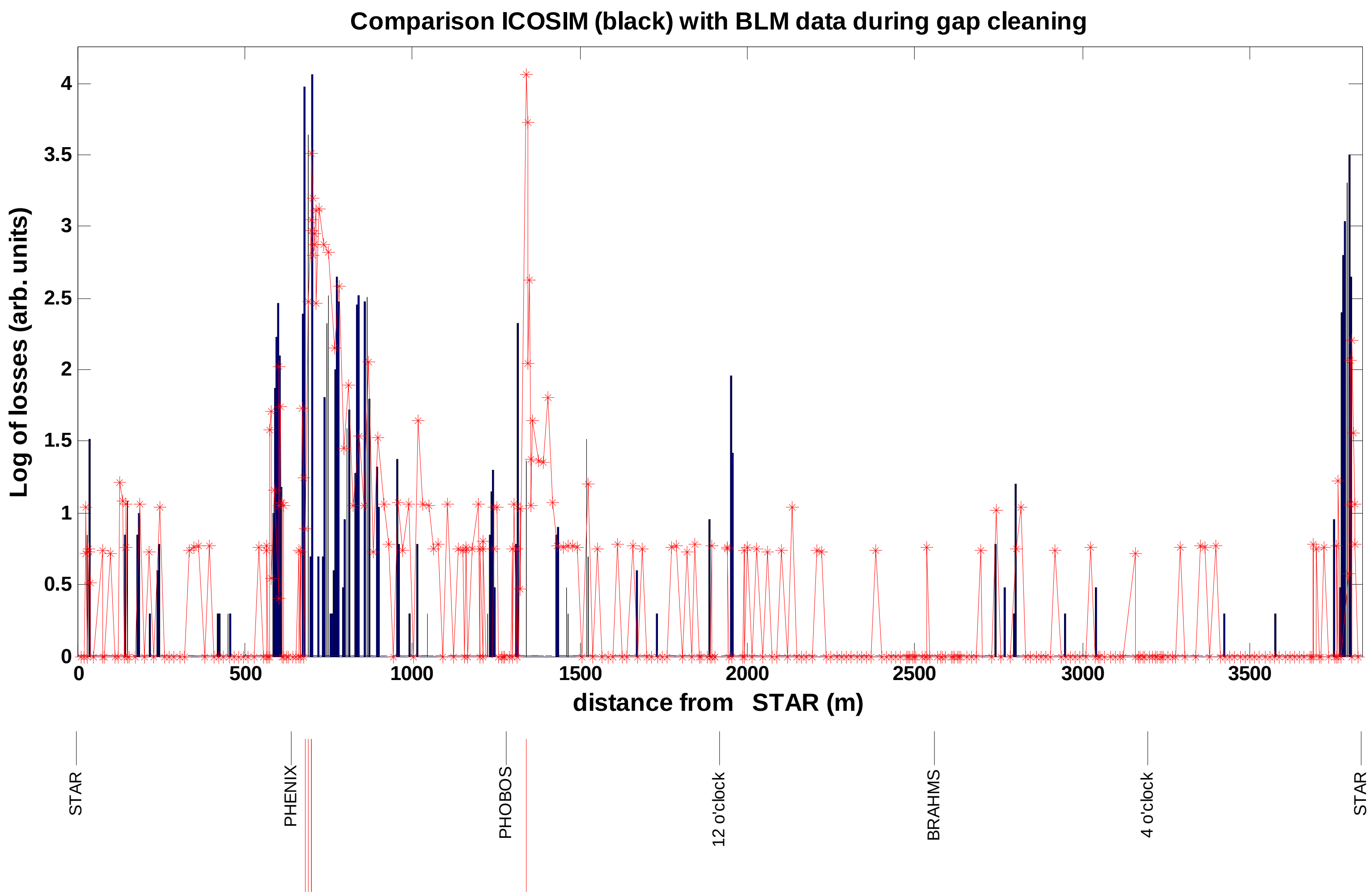
- ***Sometimes continues abort gap cleaning is off, but gap is cleaned before beam abort.***
  This is a case when BLM signals go high and loss map for one ring can be obtained by subtracting loss map before cleaning from loss map during cleaning.

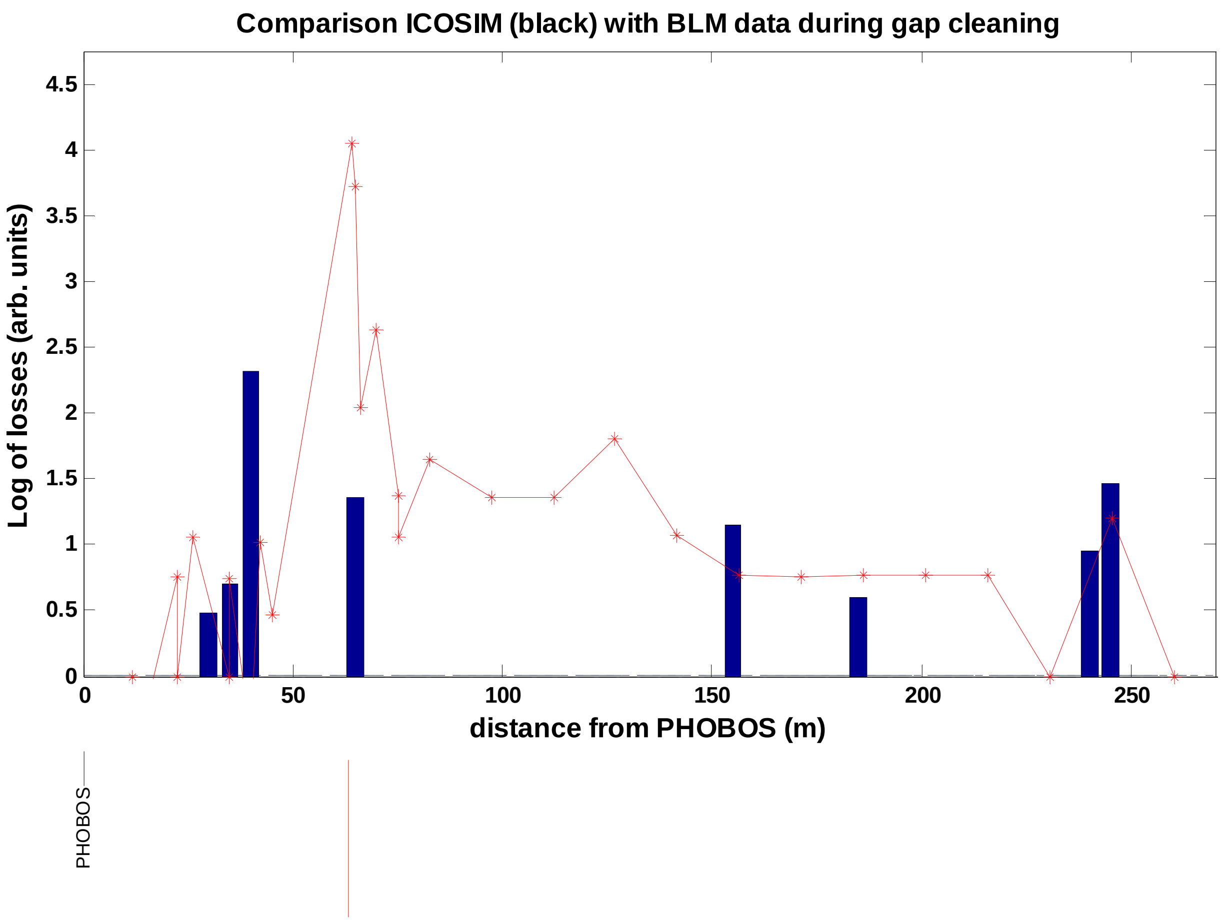
- ***To start with some existing log files of loss maps were used. Data obtained in a more controlled manner would be desirable.***

- ***An overall calibration factor and the ratio between BLM's on cold and warm sections were used as free fit parameters.***

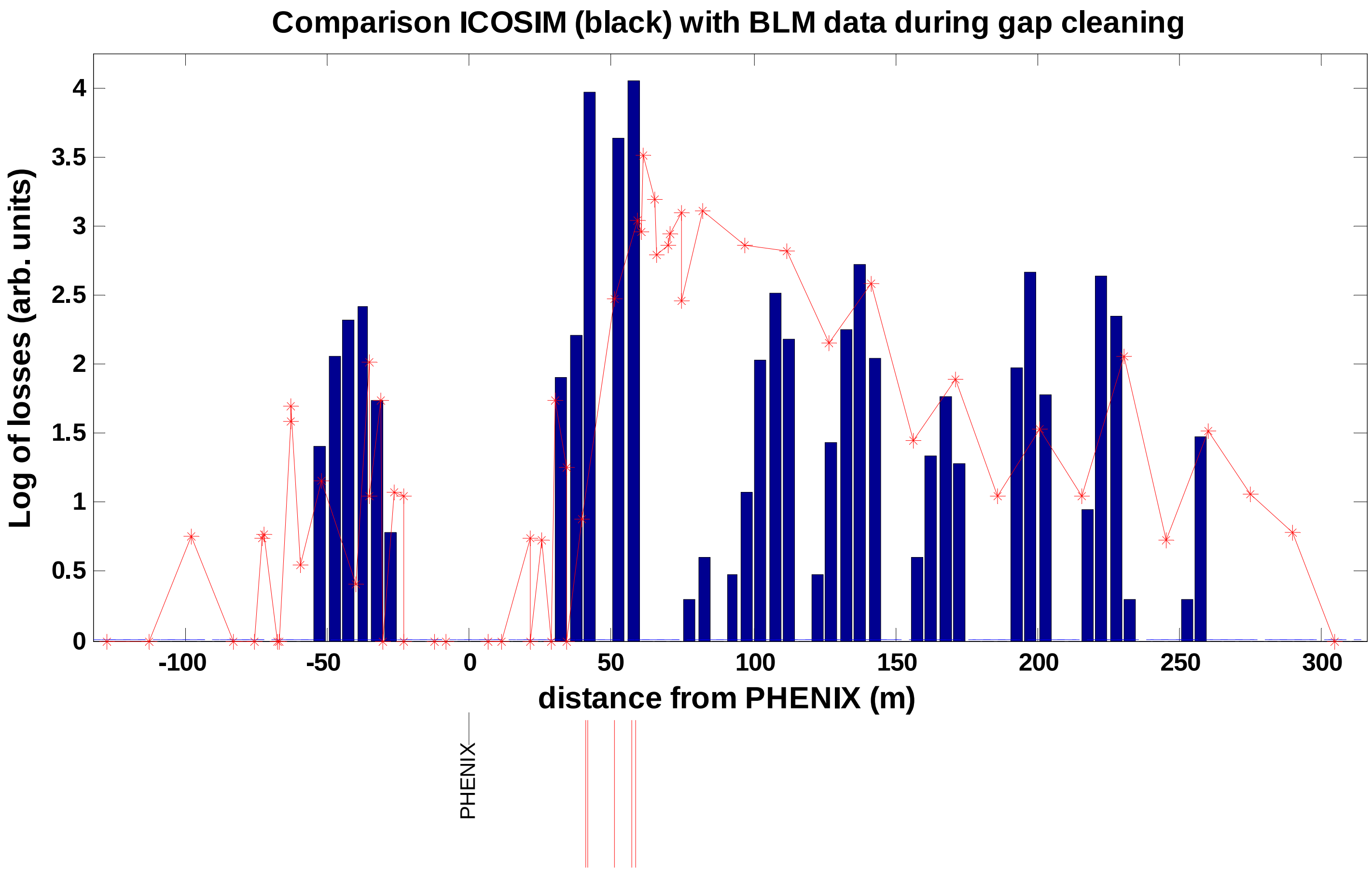
RHIC BLUE downstream of collimators during abort gap cleaning

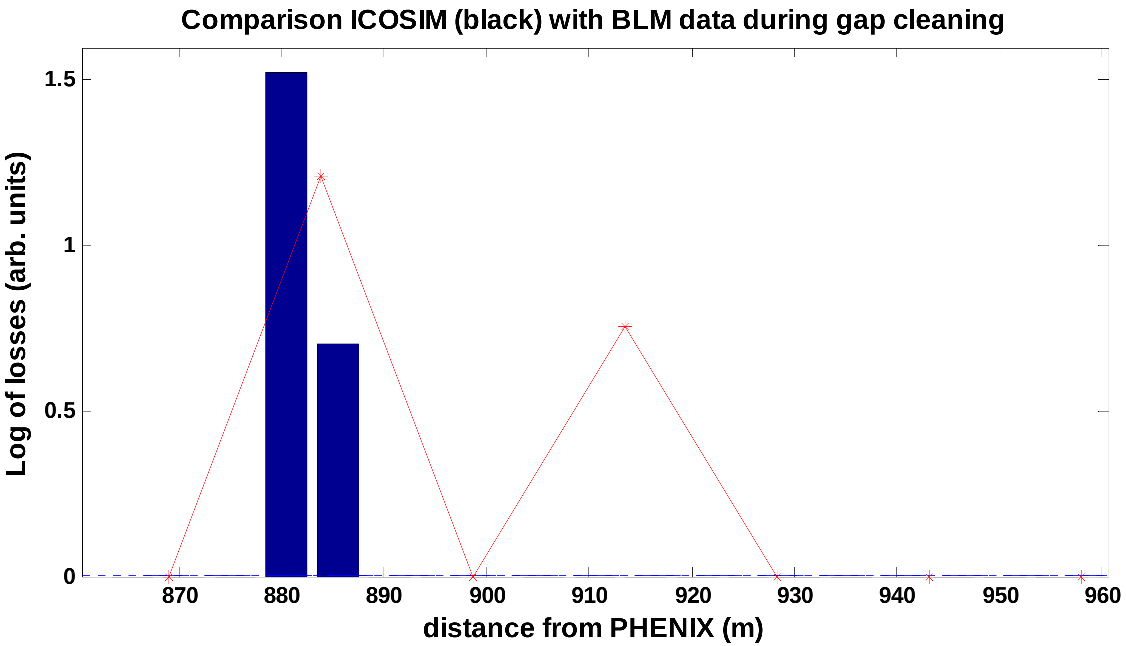


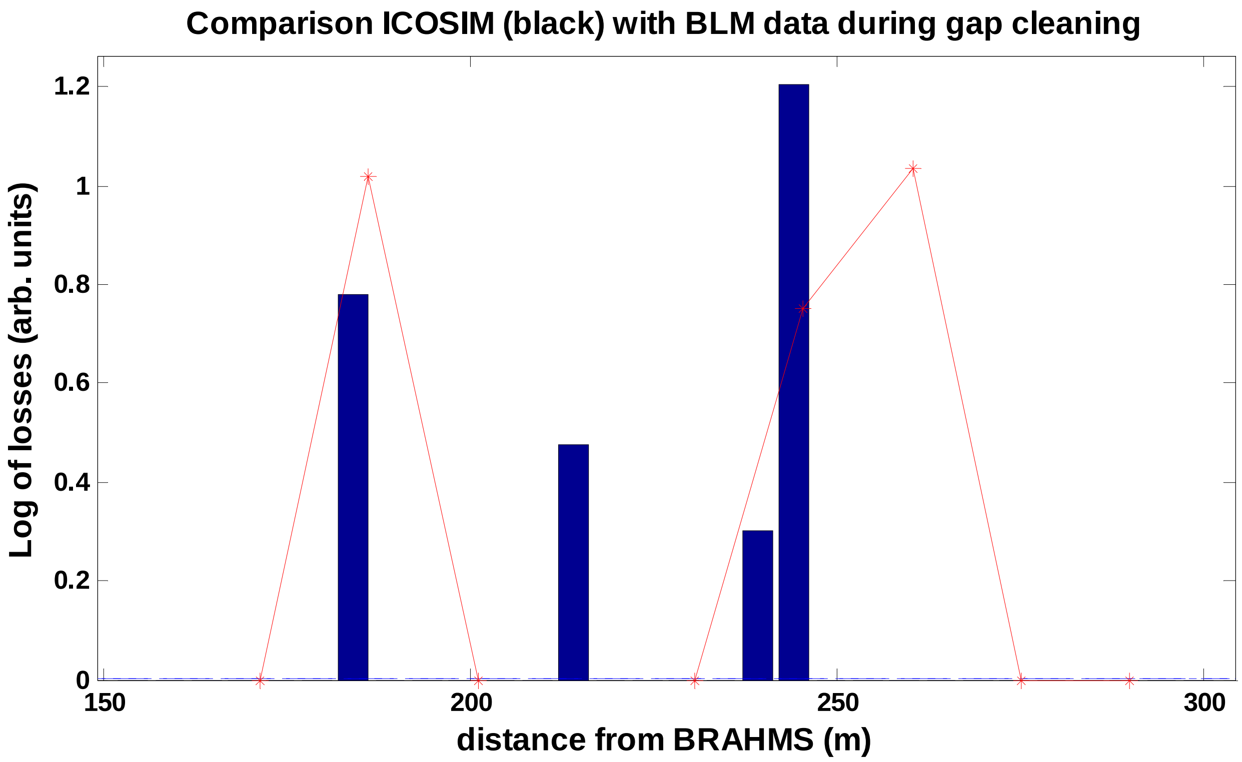

Comparison ICOSIM (black) with BLM data during gap cleaning
Log of losses (arb. units)
0
0.5
1
1.5
2
2.5
3
3.5
4
0
500
1000
1500
2000
2500
3000
3500
distance from STAR (m)
STAR
PHENIX
PHOBOS
12 o'clock
BRAHMS
4 o'clock
STAR

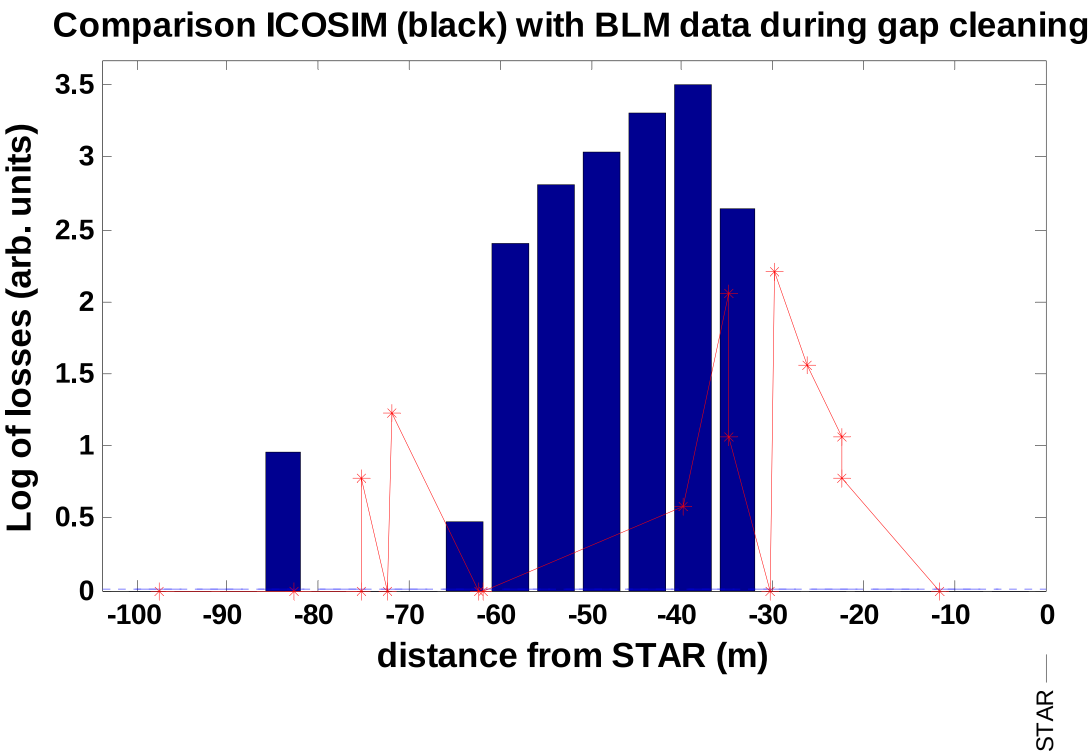


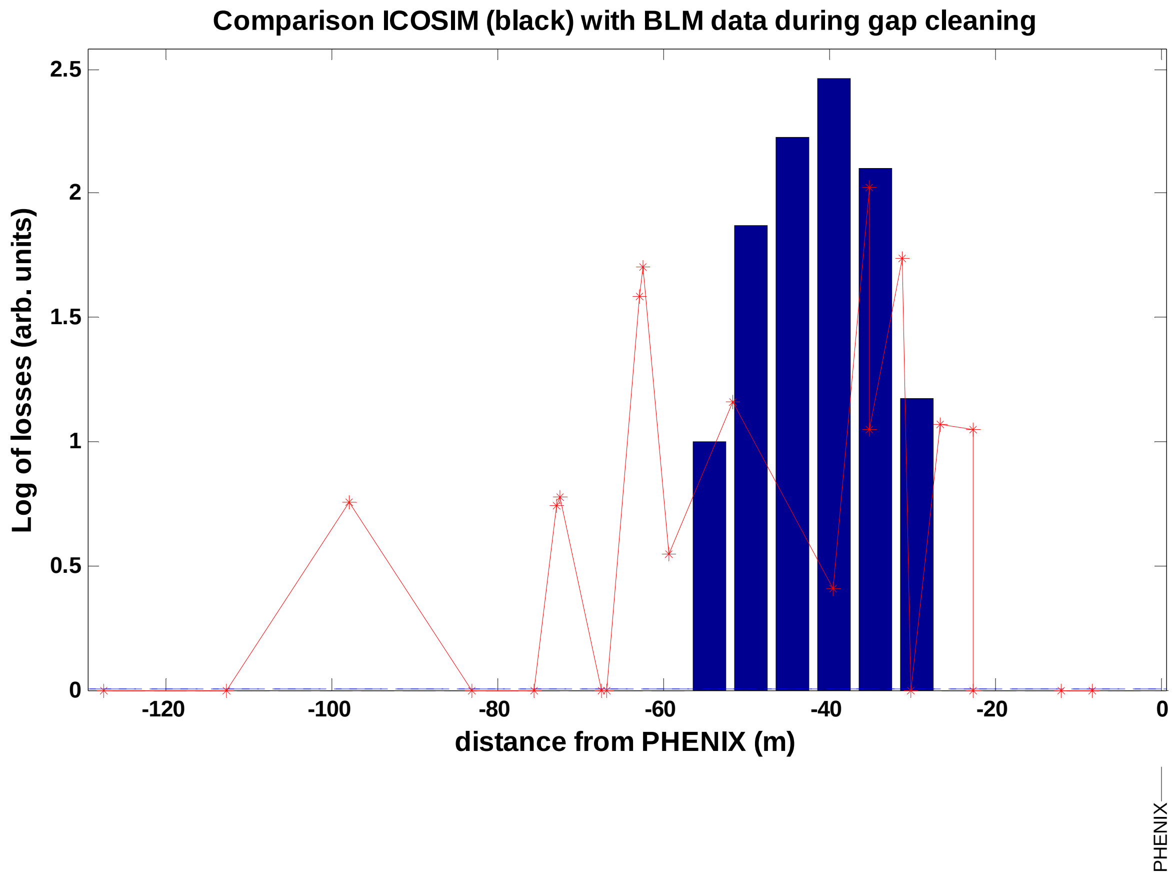
Comparison ICOSIM (black) with BLM data during gap cleaning
Log of losses (arb. units)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
50
100
150
200
250
distance from PHOBOS (m)
PHOBOS


Comparison ICOSIM (black) with BLM data during gap cleaning
Log of losses (arb. units)
0
0.5
1
1.5
2
2.5
3
3.5
4
-100
-50
0
50
100
150
200
250
300
distance from PHENIX (m)
PHENIX


Comparison ICOSIM (black) with BLM data during gap cleaning
Log of losses (arb. units)
1.5
1
0.5
0
870
880
890
900
910
920
930
940
950
960
distance from PHENIX (m)


Comparison ICOSIM (black) with BLM data during gap cleaning
1.2
1
0.8
0.6
0.4
0.2
0
150
200
250
300
distance from BRAHMS (m)
Log of losses (arb. units)


Comparison ICOSIM (black) with BLM data during gap cleaning
Log of losses (arb. units)
3.5
3
2.5
2
1.5
1
0.5
0
-100
-90
-80
-70
-60
-50
-40
-30
-20
-10
0
distance from STAR (m)
STAR


Comparison ICOSIM (black) with BLM data during gap cleaning
Log of losses (arb. units)
2.5
2
1.5
1
0.5
0
-120
-100
-80
-60
-40
-20
0
distance from PHENIX (m)
PHENIX

Conclusions on benchmarking

- **First comparisons show that ICOSIM results are not unreasonable**
- **For RHIC parameters the separation between different ion species is less pronounced. Therefore difficult to get results on ion fragmentation in different channels.**
- **More data with better controlled conditions would be desirable, i.e. loss maps with only one collimator in and all others out.**

Some observations

- Quite sophisticated ramp.
  - Beam goes through transition, thus requiring phase and chromaticity flip
  - squeeze starts after transition to avoid change of sign for dB/dt
  - control of hor./vert. coupling during ramp remains an issue
  - control of chromaticity during ramp remains an issue
- Tune meter kicker is a key instrument, although the hardware is relatively simple (fixed pulse height and length, but timing and sign programmable).
- BLM's thresholds programmed as function of beam energy, particle species and BLM. Values empirically. Original theoretical values were to high.
- Bunched beam Schottky monitor key instrument for emittance recording during store.
- Ionisation profile monitor works with experts present.
- Special loss monitors in preparation to detect ECPP beam losses in dispersion suppressor (→John Jowett)
- Emittances for Gold < Copper < Protons
- Proton energy so far limited to 100 GeV by vertical COD in quadrupoles (~300 μm rms). Vertical COD ~100 μm rms required to keep proton polarisation up to 200 GeV. → realignment of quadrupoles required
- Integrated luminosity for Ions better than expectation. Detectors need upgrade to profit from more integrated luminosity. Discussion ongoing if next ion runs >2007
- Naming the rings BLUE and YELLOW is very practical
- Long Island is damned cold in January
- Nevertheless you see surfers on the beach !

Acknowledgements

I enjoyed discussions with Angelika Drees, Fulvia Pilat, Wolfram Fischer, Dejan Trbojevic, Thomas Roser, Steven Tepikian, Ilan Ben-Zvi, Feng Zhou and Vitali Yakimenko.

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