Operations Analysis

Presented to

RHIC Facility Annual Science and Technology Review

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Operations Analysis

Machine performance (→beam physics)

Machine uptime (→operations, systems)

- Operation analysis naturally part of daily operations running

How we address it in the organization:

- **RHIC Retreat** — **Yearly overall operations review and plans**
  CAD staff and management, experiment coordinators, limited number of external visitors
- **Operations Analysis Group** — **focused on performance, topical**
  AP, operations, instrumentation groups (weekly)
- **Machine/program specific** — **RHIC, Injectors, Spin** (weekly)
- **Trouble Committee** — **focused on system reliability, failure review**
  operations staff, systems experts, chief engineers
  (ad hoc, typically 1-2 times/month)

Outline

Machine performance→ luminosity

- Recall performance Run-8 ions
- Performance limits for ion-ion operations
- Improvements
- Recall performance Run-8 PP
- Performance limits for PP operations
- Improvements

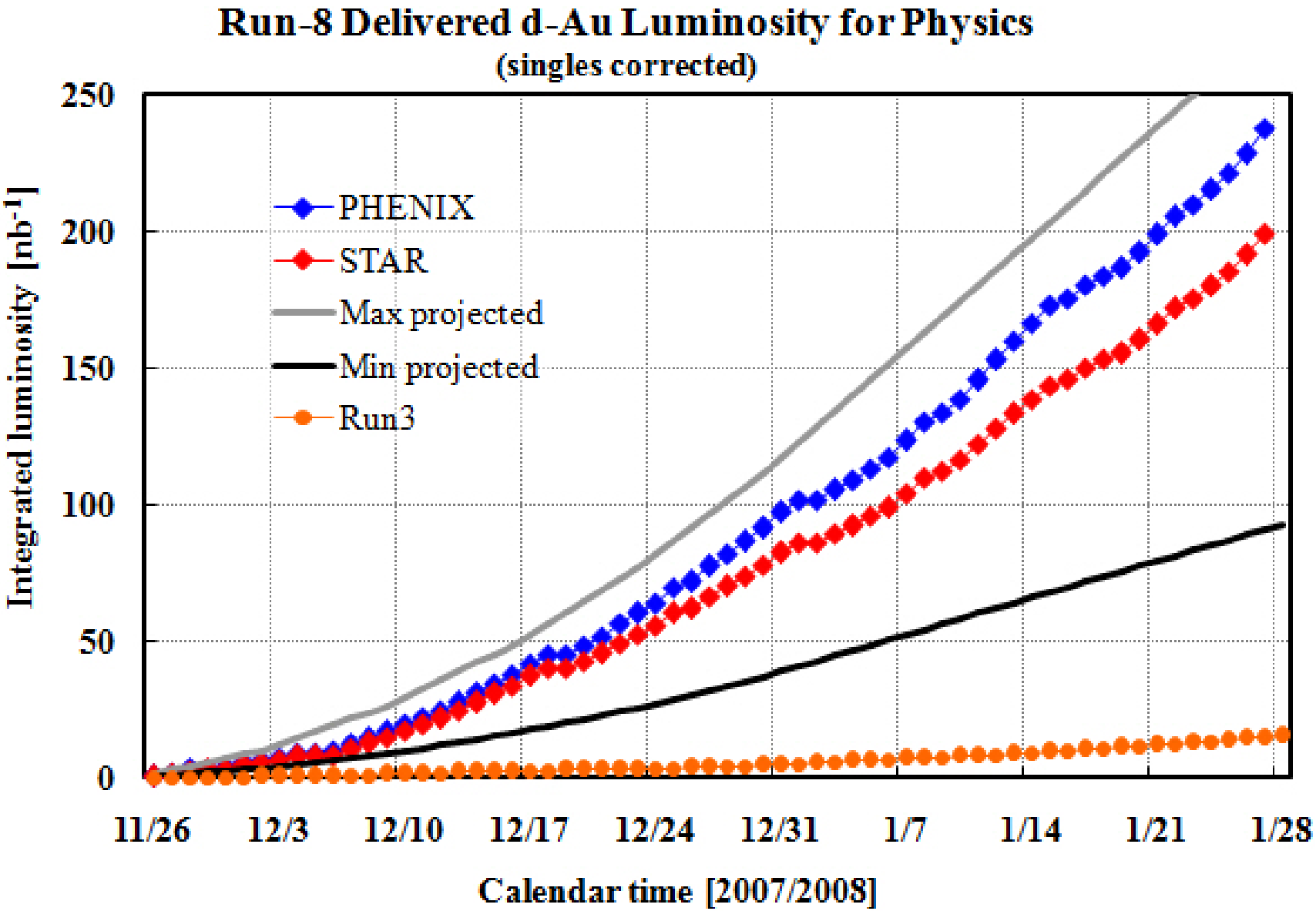
Machine uptime, reliability→integrated luminosity

- Machine uptime history
- Failure data, run-7 vs. run-8. Improvements: systems, operations, maintenance
- This year: discuss power supplies, human error
- Further Improvements, Run-9 and beyond

  Systems (More PS, Low Level RF, Upgrade Access Controls Systems)

  Operations and maintenance: organization and practices

  Infrastructure (MCR upgrade, spare database and consolidation in bld. 912)
- Challenge to operations: aging infrastructure


Run-8 Delivered d-Au Luminosity for Physics
(singles corrected)
Integrated luminosity [nb-1]
250
200
150
100
50
0
PHENIX
STAR
Max projected
Min projected
Run3
11/26
12/3
12/10
12/17
12/24
12/31
1/7
1/14
1/21
1/28
Calendar time [2007/2008]

Improvements for ion-ion luminosity

Main limitations: IBS, transition instabilities

- Reduction in β^* (from present 80cm to 50cm, +60%)
- Lattice with reduced IBS (+25%)
- Blue longitudinal stochastic cooling (+15%)
- Transverse stochastic cooling (+400%)
- Transverse damper, scrubbing (+40%)
- RHIC 56 MHz SRF (+30-50%)
- Transition crossing

  longitudinal damper of quadrupole oscillations

  2 rings crossing transition at different times

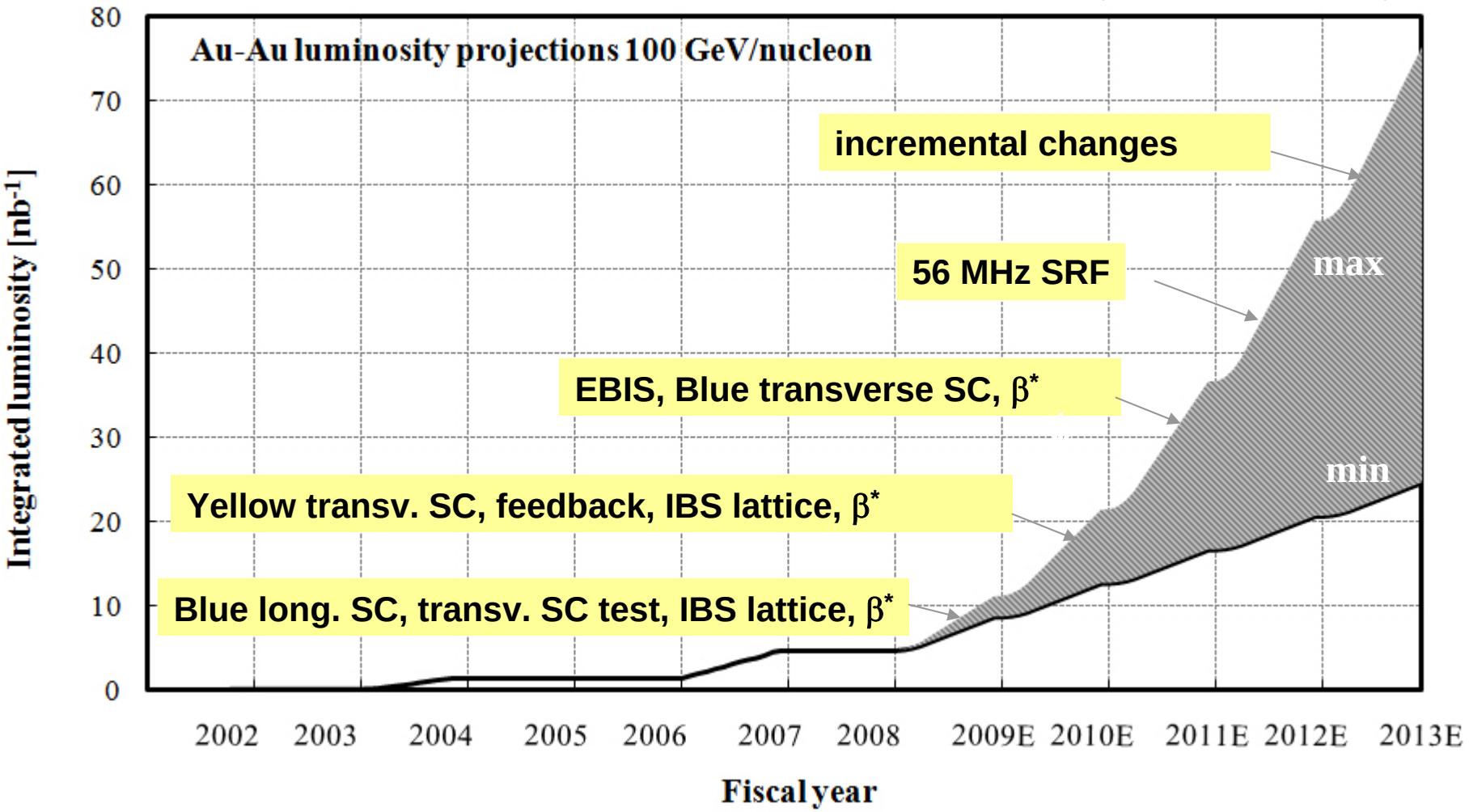
  yellow dipole radius feedback

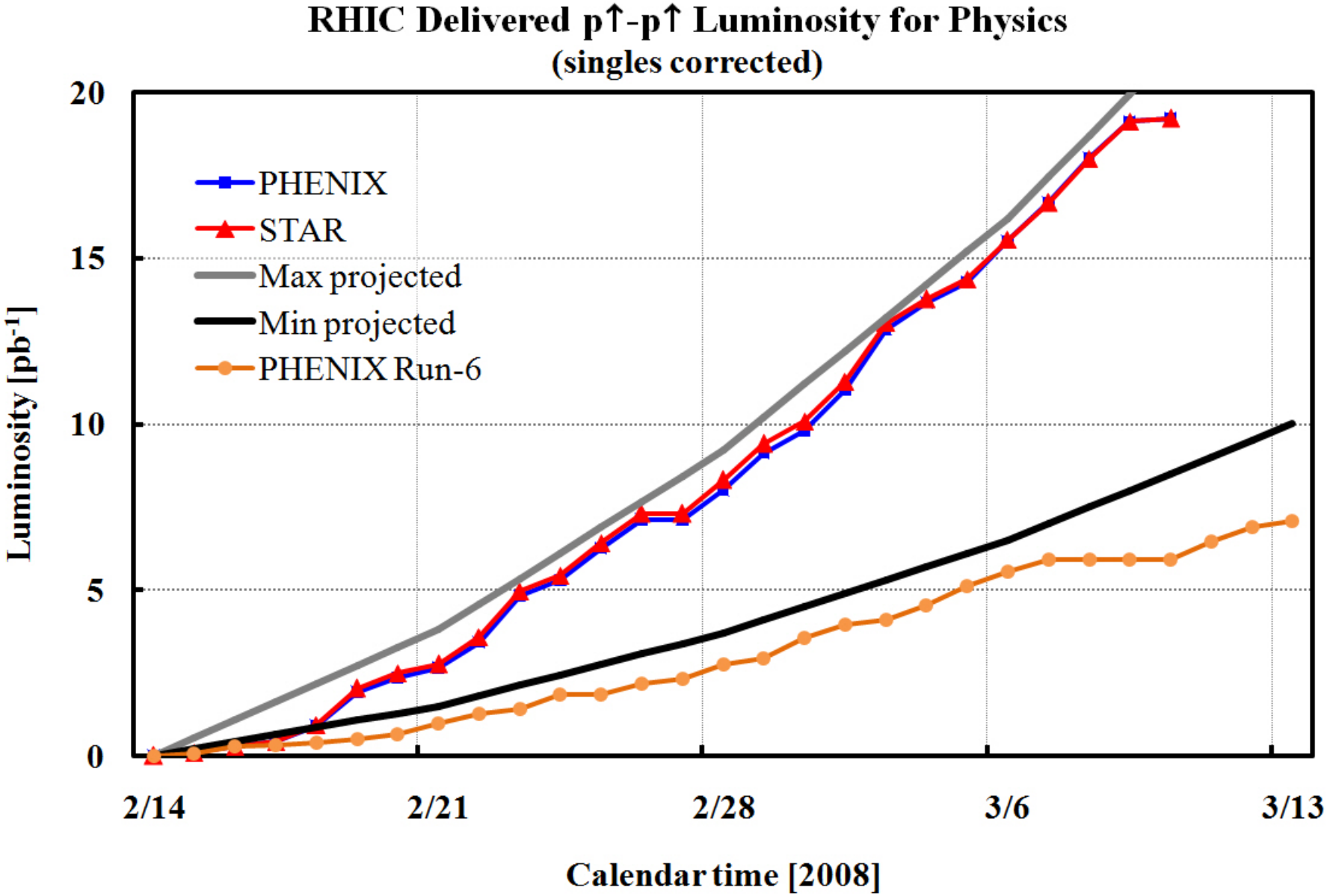
  better control of chromaticity jump at transition

Au–Au luminosity timeline

Projections for Au-Au luminosity assuming 12 weeks of physics in every year

min: no performance increase max: success of all major upgrade projects




RHIC Delivered p↑-p↑ Luminosity for Physics
(singles corrected)
Luminosity [pb-1]
20
15
10
5
0
PHENIX
STAR
Max projected
Min projected
PHENIX Run-6
2/14
2/21
2/28
3/6
3/13
Calendar time [2008]

Improvements for P-P luminosity, polarization

Main limitations: polarization of injectors, beam-beam

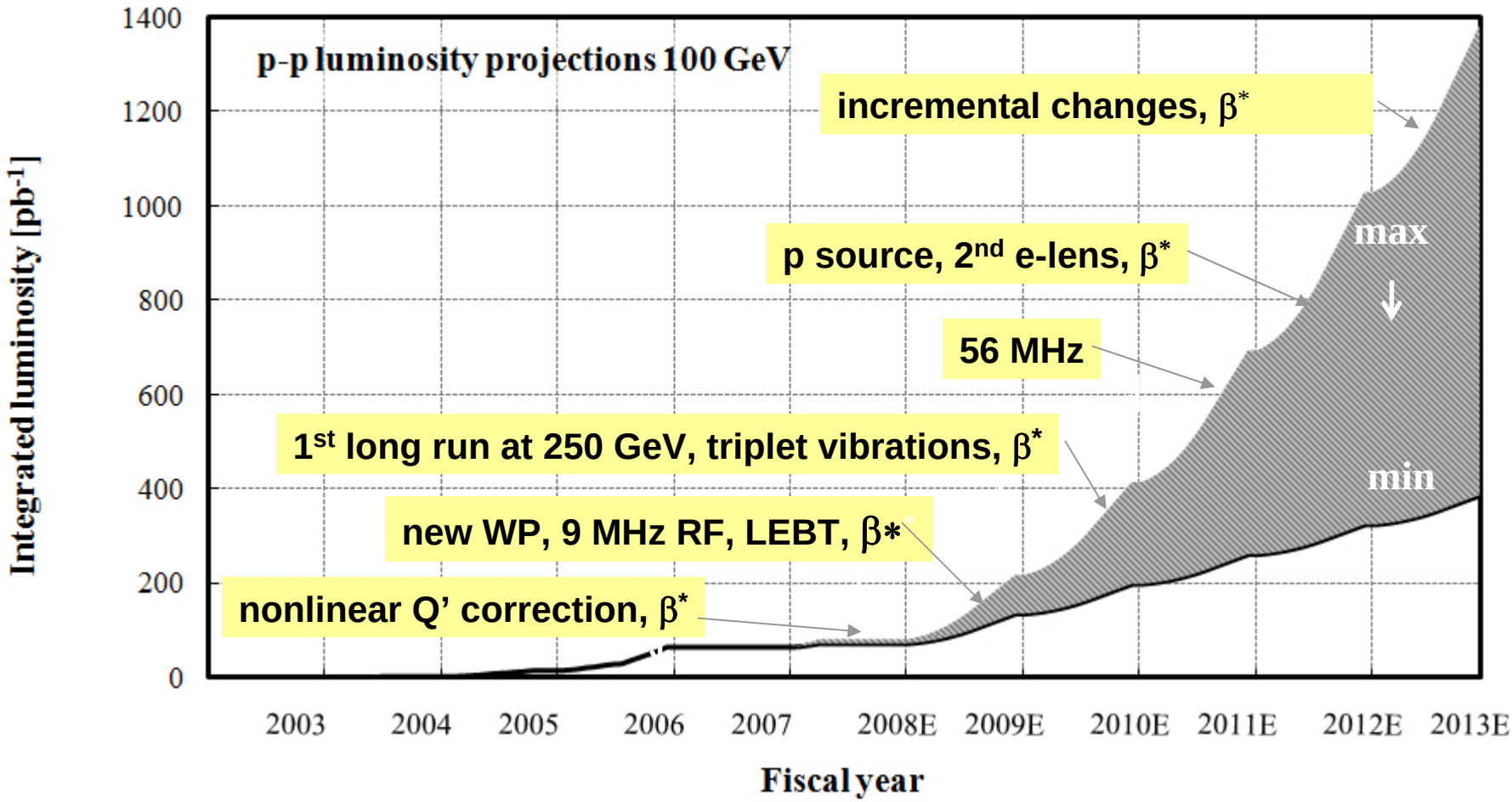
- Reduction in β^* (from 90cm to 50cm, +80%)
- Nonlinear chromaticity correction (+30%)
- 9 MHz cavity (+25% at β^* = 1m)
- LEBT/MEBT + Booster injection modification (+20%)
- Eliminate triplet vibration→ Near (half) integer working point (+40%)
- 56 MHz cavity
- Electron lens (+100%?)

- Polarization improvements in injectors and RHIC
  (Polarization:45-60%→70%)

P-P luminosity timeline

5-year projections for p-p luminosity assuming 12 weeks of physics in every year

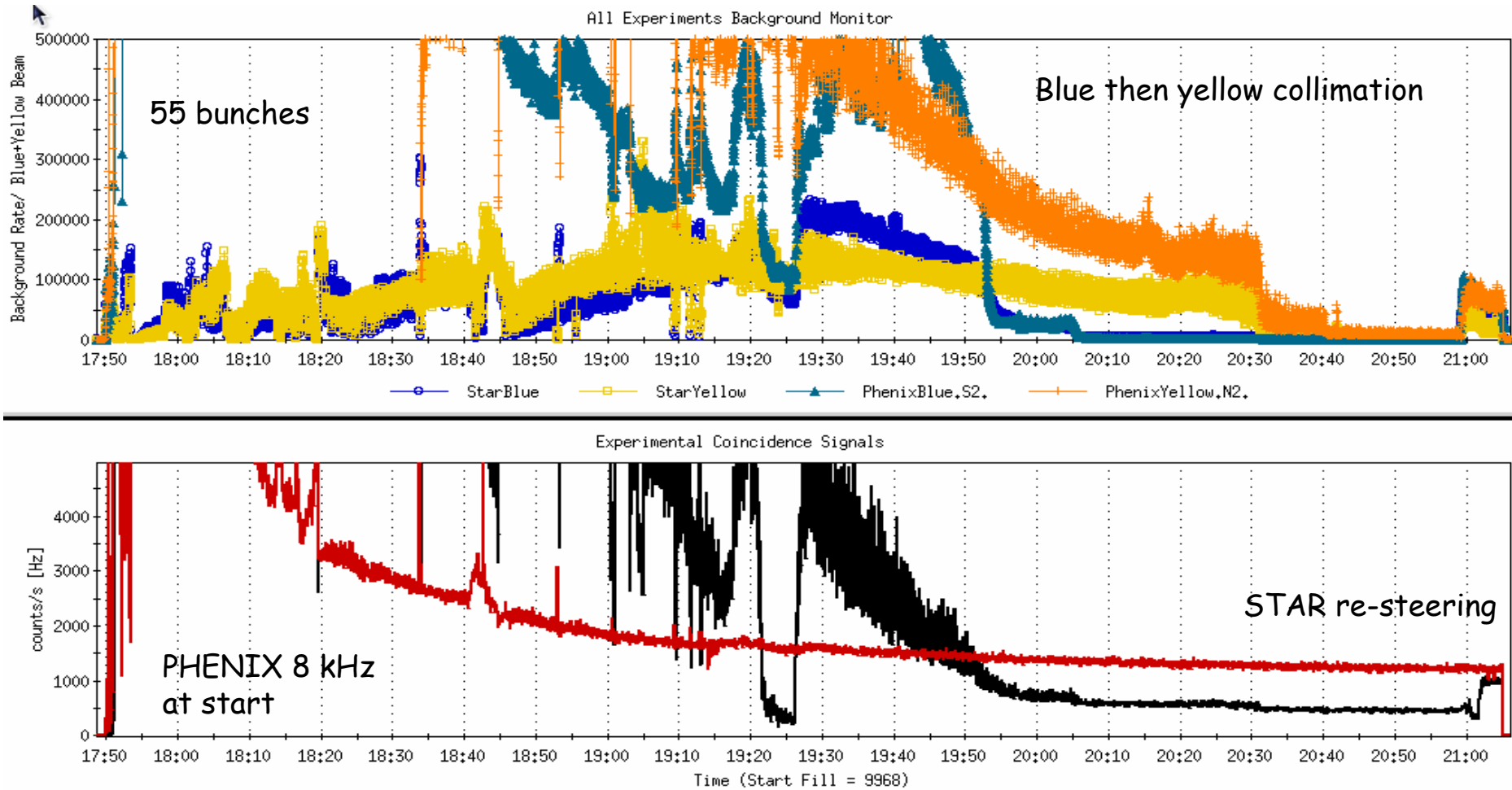
min: no performance increase max: success of all major upgrade projects



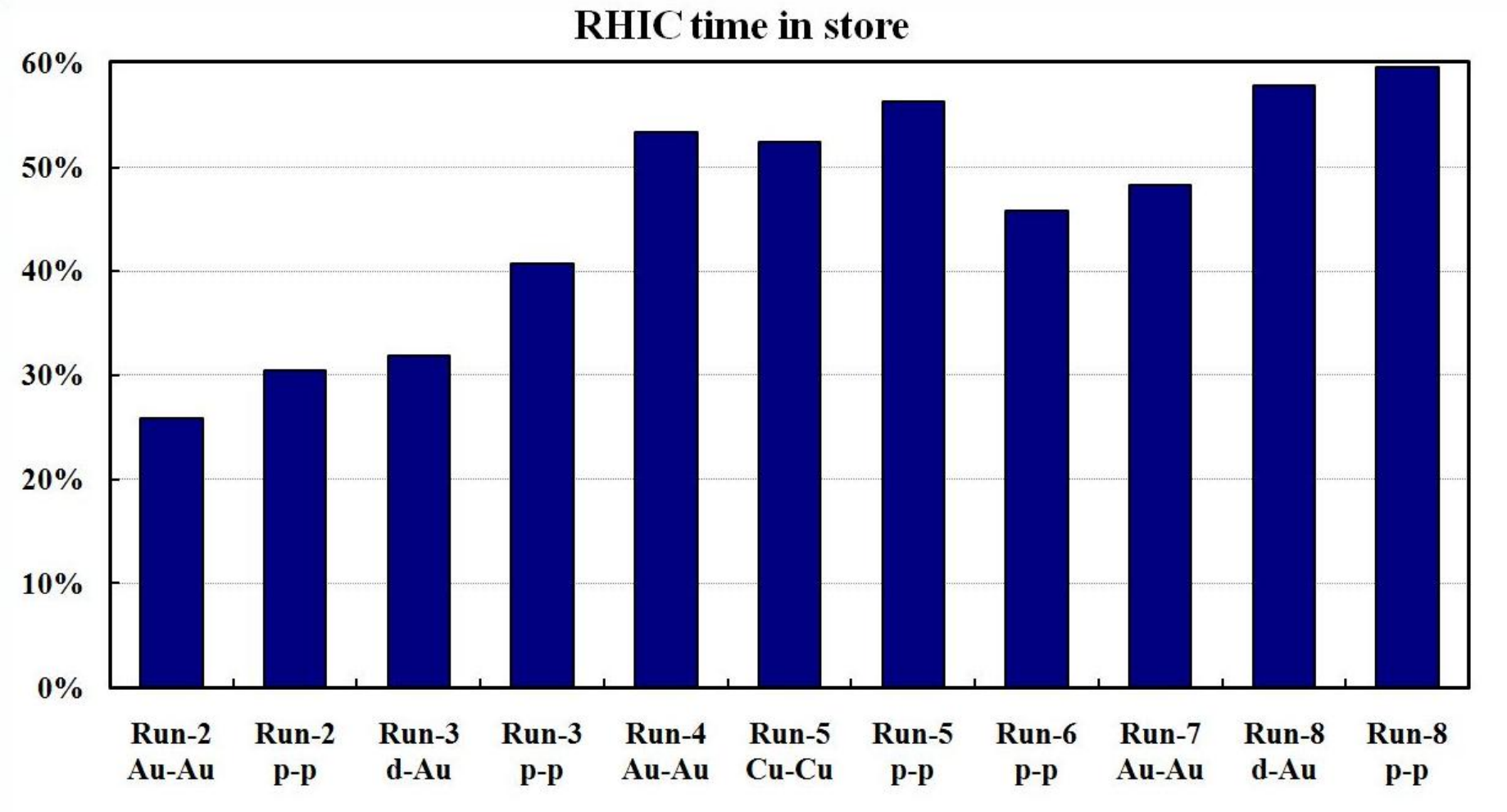
Run-8 Low Beta Developments

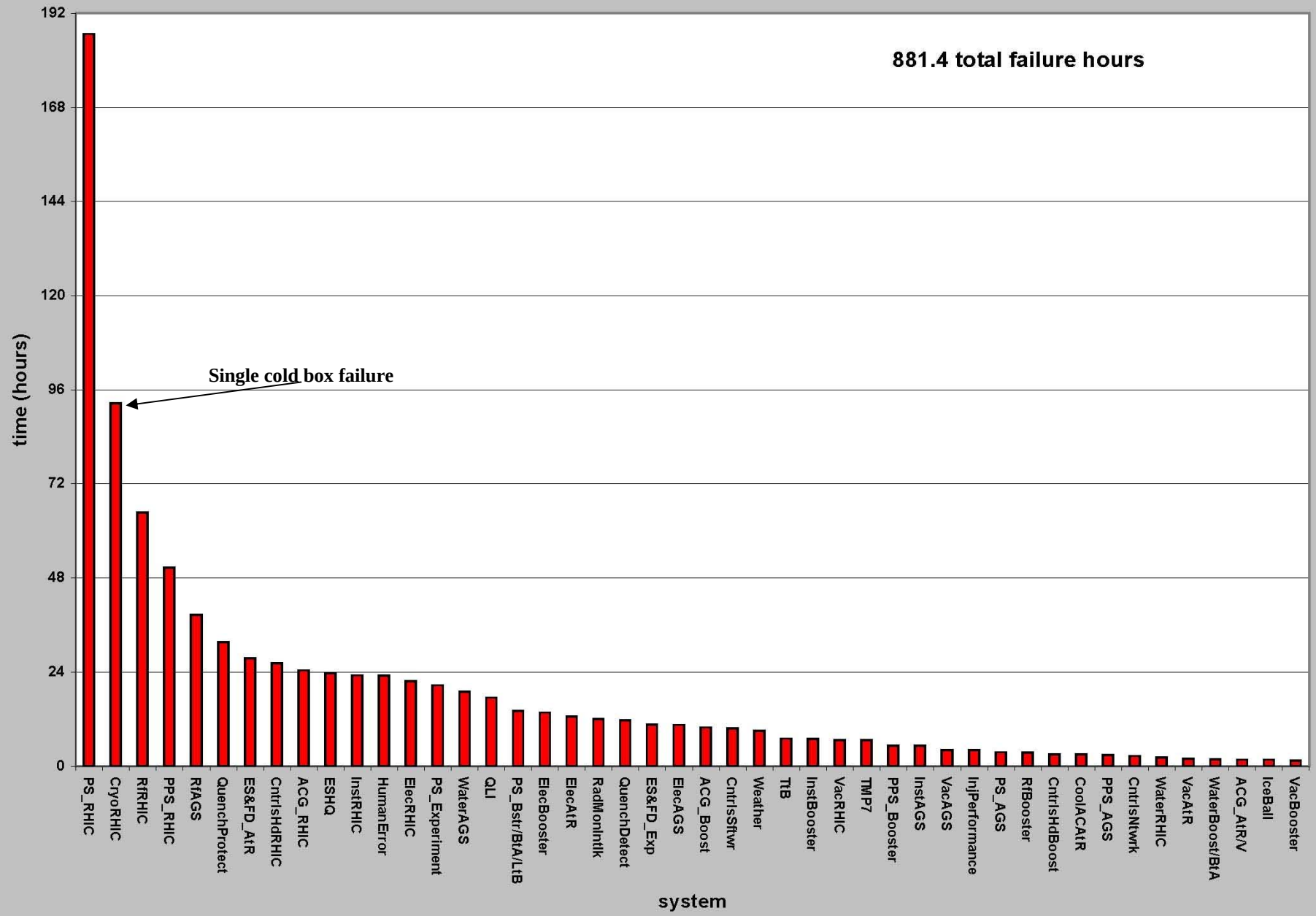
- Commissioned lattice with β^*=0.75m in blue and yellow for d-Au operations during APEX → 30% increase in luminosity
- Nearly commissioned β^*=0.65m for PP operations at 100 GeV
- There are presently no show-stoppers for adoption for Run-9
  - This is equivalent to **β^*=0.40m** at 250 GeV (but present power supplies can't do this)
  - Ramp efficiencies are good: **93-95%** in both rings
  - **Nonlinear chromaticity correction** works, but needs careful ramp tuning
  - **Collimation** worked with no beam decay penalty
  - Experiments agree that **backgrounds** were reasonable
  - 55 bunches, PHENIX peak 8-10 kHz, emittance 20-30π μm, STAR consistent after steering, with singles correction
- We will plan for a low β^* lattice independently on decision on phase advance in the arc (IBS suppression lattice)
- Open issues (to be evaluated during operations)
  - Integrated luminosity and luminosity lifetime
  - 10 Hz generated by low-β triplets; orbit, collimation reproducibility
  - Yellow nonlinear chromaticity, dispersion, optics

Low Beta 0.65: Background, steering, and collimation



- D-Au β=0.65m lattice collimation worked well; operational backgrounds achieved


RHIC time in store
60%
50%
40%
30%
20%
10%
0%
Run-2 Au-Au
Run-2 p-p
Run-3 d-Au
Run-3 p-p
Run-4 Au-Au
Run-5 Cu-Cu
Run-5 p-p
Run-6 p-p
Run-7 Au-Au
Run-8 d-Au
Run-8 p-p


Run 7 Failures by system (to 6/26)
881.4 total failure hours
Single cold box failure
time (hours)
192
168
144
120
96
72
48
24
0
PS_RHIC
CryoRHIC
RfRHIC
PPS_RHIC
RfAGS
QuenchProtect
ES&FD_AtR
CntrlsHdRHIC
ACG_RHIC
ESHQ
InstRHIC
HumanError
ElecRHIC
PS_Experiment
WaterAGS
QLI
PS_Bstr/BtA/LtB
ElecBooster
ElecAtR
RadMonIntlk
QuenchDetect
ES&FD_Exp
ElecAGS
ACG_Boost
CntrlsSftwr
Weather
TtB
InstBooster
VacRHIC
TMP7
PPS_Booster
InstAGS
VacAGS
InjPerformance
PS_AGS
RfBooster
CntrlsHdBoost
CoolACAtR
PPS_AGS
CntrlsNtwrk
WaterRHIC
VacAtR
WaterBoost/BtA
ACG_AtR/V
IceBall
VacBooster
system

Machine uptime

At RHIC we define uptime for operation analysis purposes as:

"time at store in collision"/calendar time

History

- typical profile for machine through early operations years
- Reach >50% in Run-4 and Run-5
- Reversal to <50% in Run-6 and Run-7

Major focus on reliability during 2007 shutdown:

- Work on major systems (example: Power supplies, RF)
- Operations practices (example: optimization of turn-around time, of troubleshooting during failure)
- Maintenance organization

→ Run-8: 58% in d-Au, almost 60% (ultimate goal) during P-P operations

Power supplies: Improvements made Before Run 8

- Reworked all PS's in service buildings

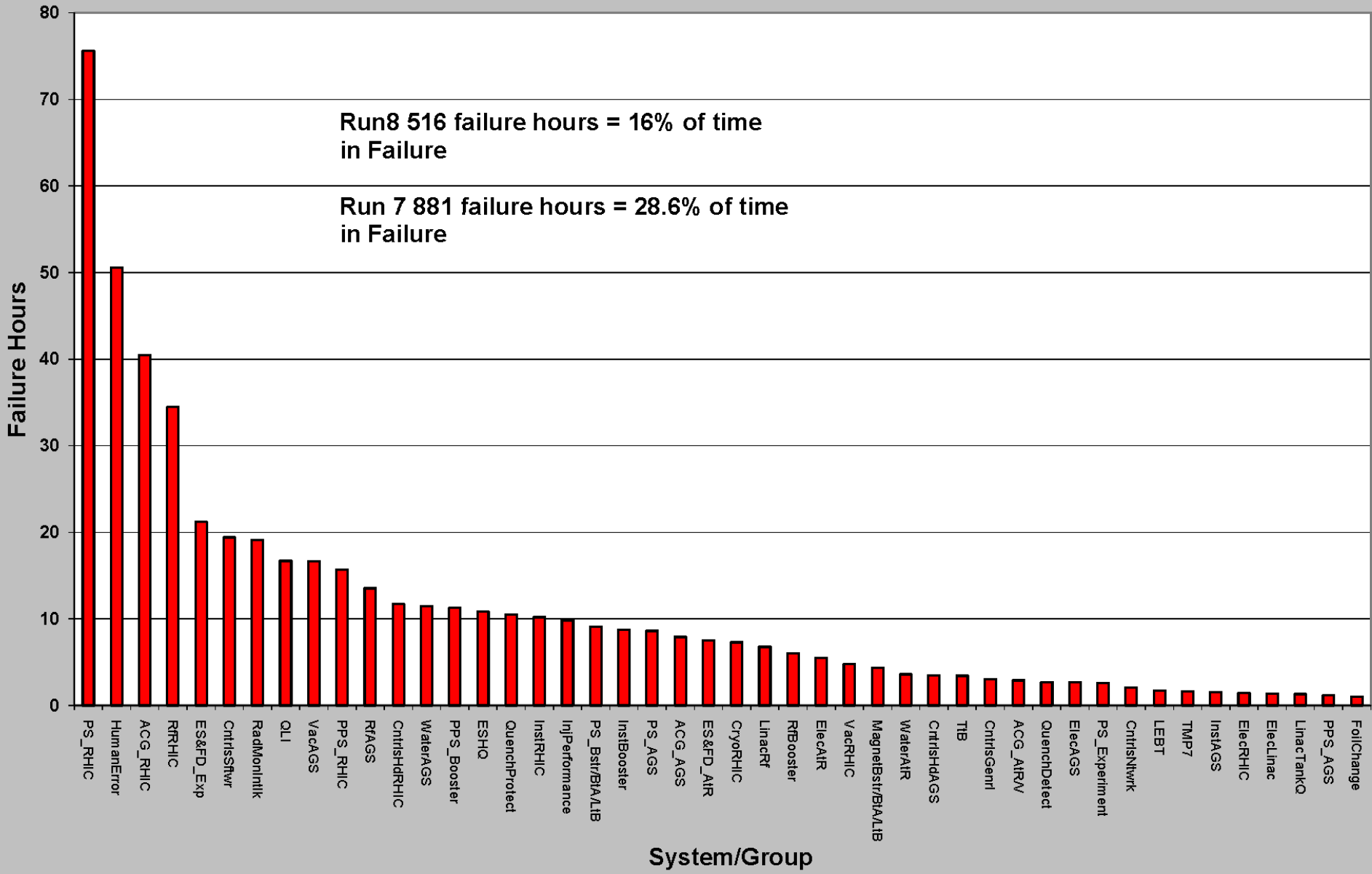
  Bipolar Suncraft 150 A IR supplies (fans, 8 factory modified)

  Bipolar Suncraft 300 A IR supplies (fans, QPA load reduced, current limited to 278A)

  Dynapowers (fans, air cooling improved for circuit breakers)
- Main power supplies
- ATR line power supplies

→ Hired one additional engineer

Run8 Failure Hours (> 1 Hr.) by Group/System



RHIC PS performance data

Average RHIC PS Failure Hours/Week

fy01-fy02	fy03	fy04	fy05	fy06	fy07	fy08
18.28	4.36	3.29	2.4	4	8.89	3.78

MTBF of RHIC due to any PS Failure

	HERA e+p 1996 (comparison only)	RHIC Run 4	RHIC Run 5	RHIC Run 6	RHIC Run 7	RHIC Run 8
MTBF_M (hours)	22.3	20.48	30.79	28.23	14.74	30.28
Number of Problems	238	148	138	109	182	96

What would be the %AV of RHIC be if only RHIC ps Failures

	HERA e+p 1996 (comparison only)	RHIC Run 4	RHIC Run 5	RHIC Run 6	RHIC Run 7	RHIC Run 8
AV%	96.6	91.97	97.09	95.03	90.87	92.18
Number of Problems	238	148	138	109	182	96

MTBF of an individual PS Failure

	HERA e+p 1996 (comparison only)	RHIC Run 4	RHIC Run 5	RHIC Run 6	RHIC Run 7	RHIC Run 8
MTBF (hours)	29310	19106	27989	26339	14161	29098
Number of P.S.'s	1166	909	909	933	961	961

Maintenance and Repair

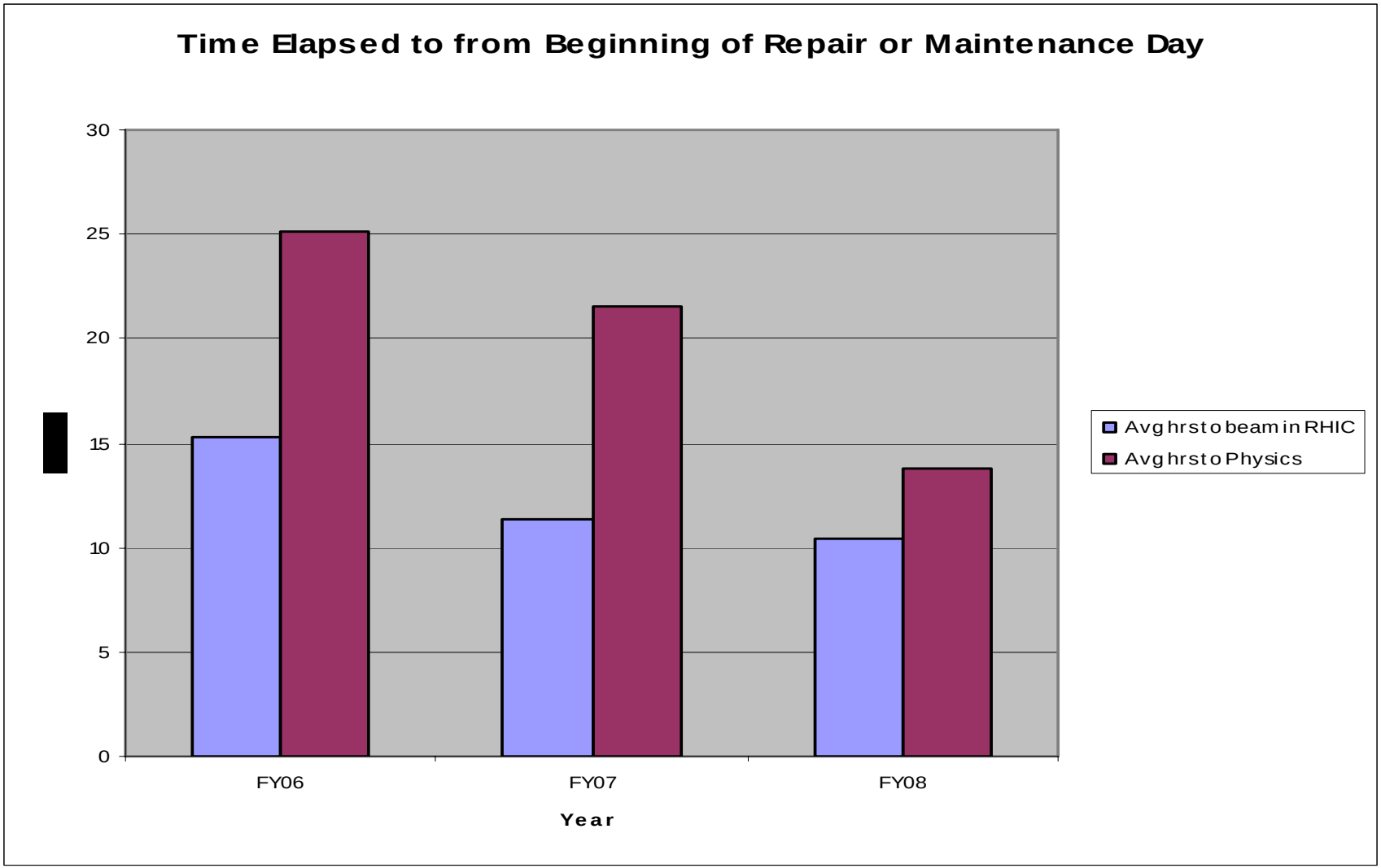
- Major improvement in (scheduled) maintenance organization and repairs
  - Pre-set **access time**
  - **Approval process**
  - **Ownership**- Affected group re-affirms that systems are operational before jobs are completed
  - **Closeout Statements**- Operational test results, owner accord and future testing improvements
  - **Documentation**
  - **Post mortem**
  - Use and expansion of a web based Job Request System (extended to shutdown organization)
  - Results in Run-8

Injectors were operational on or before predetermined time

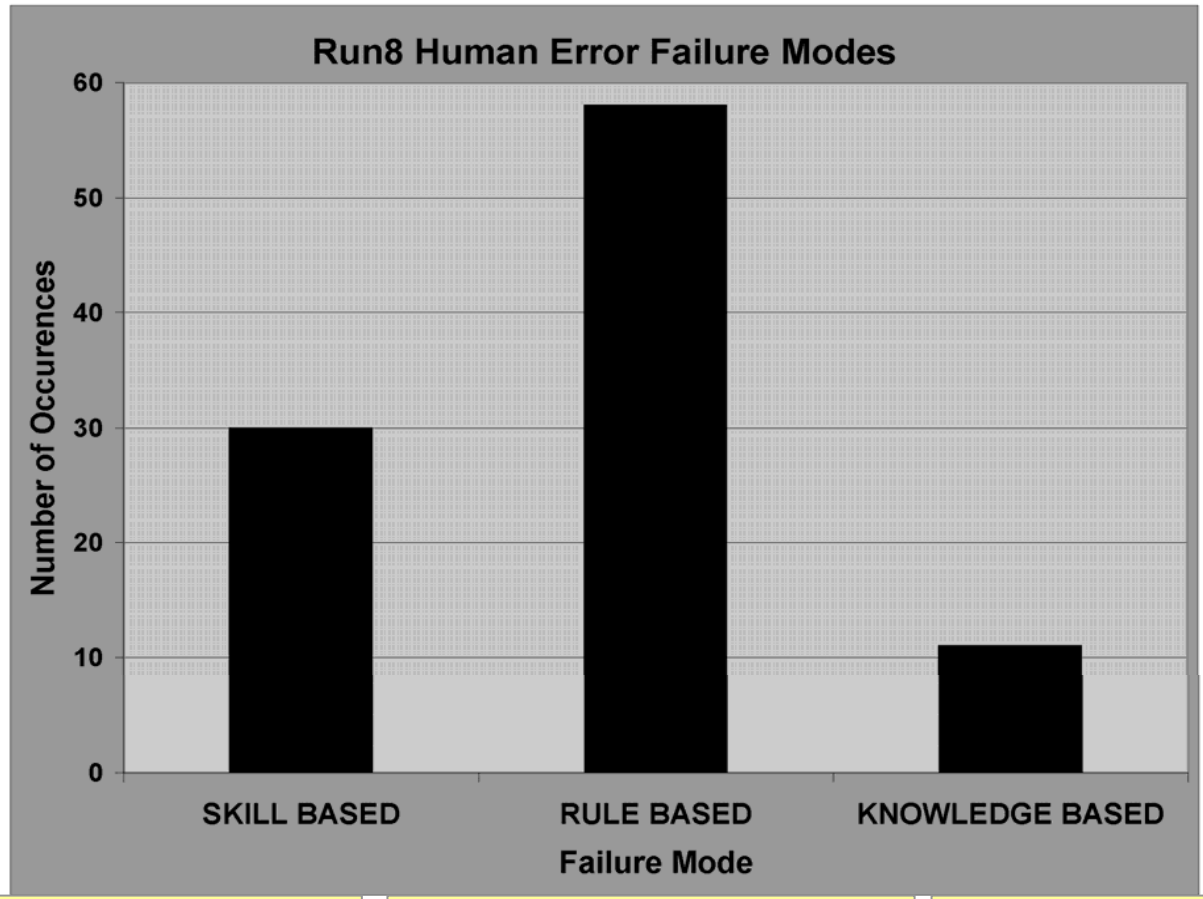
Impact of sweeps minimal

Additional support personnel was made available in recovery periods

Recovery time after scheduled maintenance



Human error: analysis in term of human performance



Highly practiced actions
in very familiar situations
Familiarity: high
Attention required: low
INATTENTION

Based on selection of mentally
Stored rules derived from ones'
Recognition of a work situation
MISINTERPRETATION

Response to an unfamiliar situation
Person relies on knowledge of system
Familiarity: high Attention: high
INACCURATE MENTAL MODEL

Human Error statistics

- Examined 597 d-Au fill numbers
- Operations personnel
  - 13 fill terminations attributed to Operator/OC/Specialist
    - **5 Physics, 2 APEX, 5 Setup/Development**
    - Very few "rookie errors"
    - Miscommunication is most common thread
    - Improved alarming, software safeguards could help
- Support personnel
  - 24 fill terminations attributed to System Expert/Physicist
    - **9 Physics, 4 APEX, 8 Setup/Development**
    - Short- and long-term misconfigurations
    - Operational errors

Further improvements to operations reliability

Run-9 and beyond

Systems

- Further work on **power supplies** (Run-9)
- **RF systems** → upgrade of **low level RF** in AGS and RHIC
  Integration, diagnostics, flexibility (Phase-1→ Run-9 Phase 2-4: FY09-11)
- Phased upgrade of the **Access Controls system** (FY08-10)

Operations and Maintenance

- **Operations**→ improvement **procedures**, **automation**, (friendly) **competition**
- **Maintenance** → quality assurance, centralized spares database
- **Operations Integration**: consolidation of all operations and support shift personnel

Infrastructures

- **Aging infrastructures** in the injectors and RHIC complex (buildings, services, equipment) are a great challenge to efficient operations

Infrastructure plans relevant to operations:

- New Main Control Room
- Building consolidation and renovation plan

Main Control Room Upgrade

Motivations:

- **Operations integration** (1 control room for all operations and support personnel → efficiency, consolidation)
- **Technology upgrade** (fully digital, consoles, screens, ergonomics)
- **Space** (office, labs)

Realization

- Conversion of "high bay area" → **2-story building** inside the existing building
- First floor: office space
- Second Floor: new control room

Project Status:

- AIP allocated
- Bidding process completed, ordered building from contractor
- Construction 3-6 months, occupancy first floor: 6 months, completed MCR FY 2010

Building consolidation project

Mission critical infrastructure needs at C-AD:

- Consolidate shops and **storage space** in or near 911 and 912
- Modern office space and infrastructure to support upgrades
- Renovate older facilities to meet safety codes and improve energy efficiency

Infrastructure impact on operations

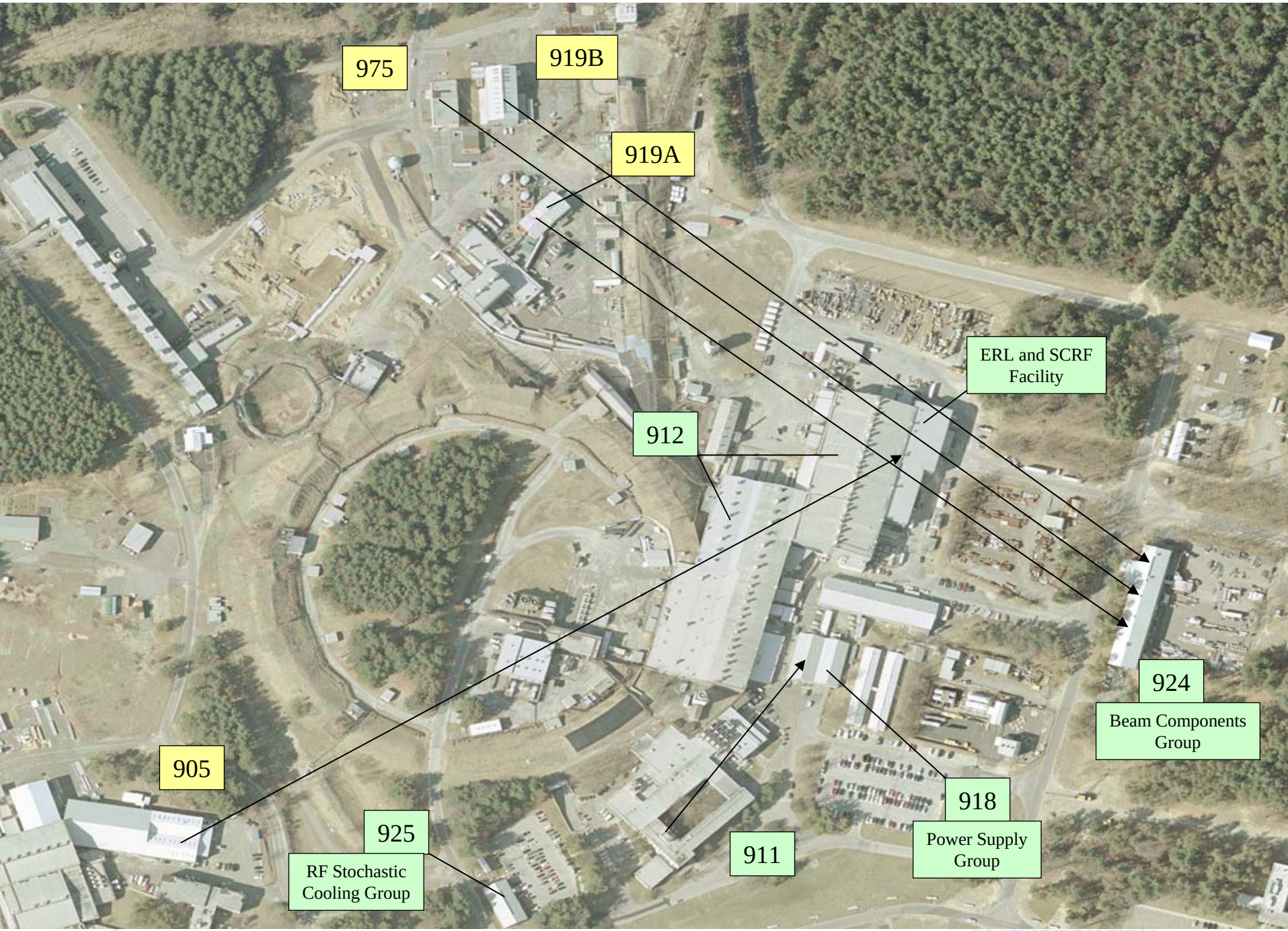
Record of infrastructure related failures 2000-07:

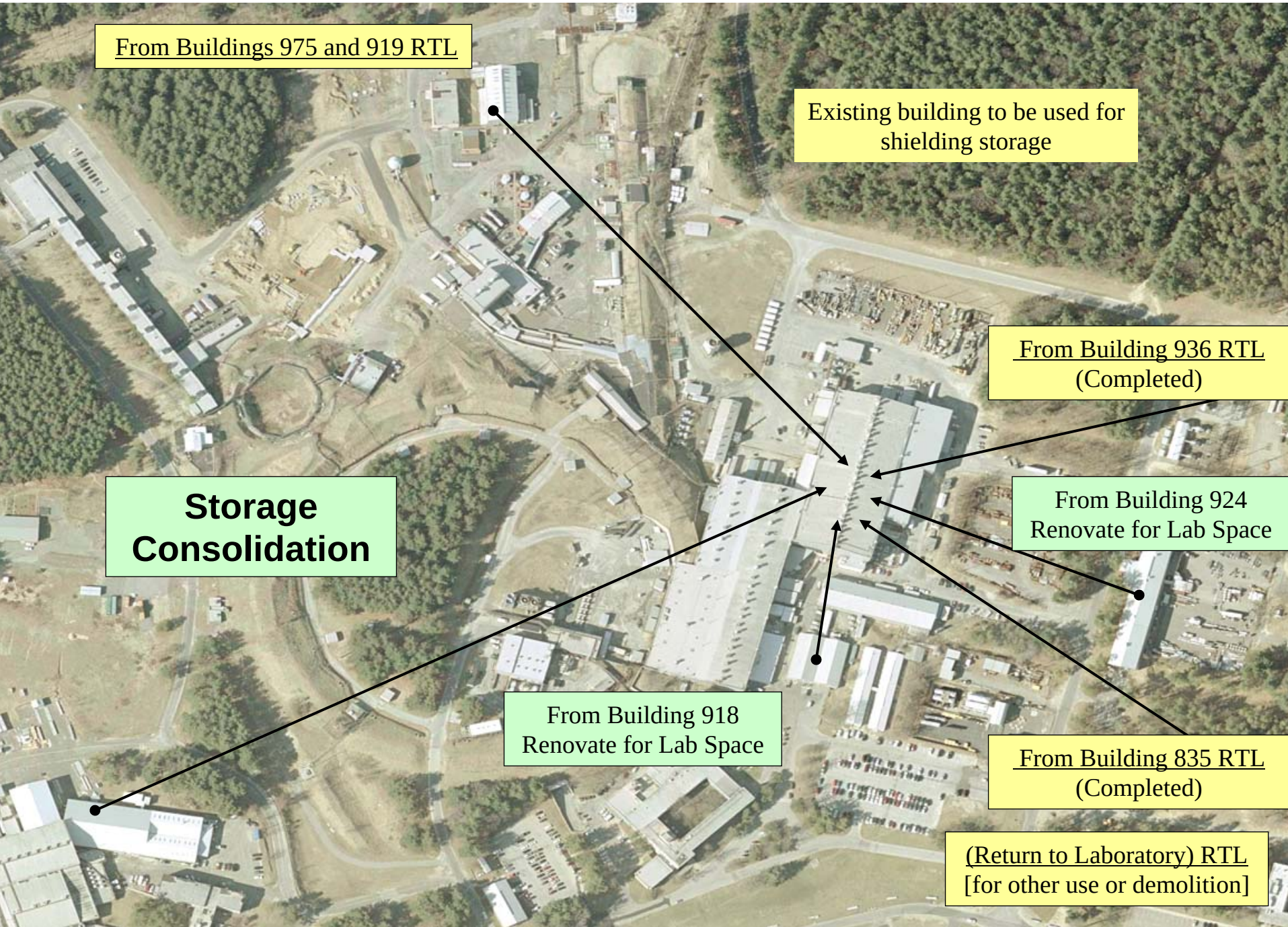
- **High temperature** (failure of AC or fans)
- **Water leaking** from roofs (on equipment and fire alarms)

Plans

Development of **building 912**

- **Centralized storage for spares and equipment**, fast access (rigging capabilities, crane)→ cost effective and minimizes downtime
- Variety of R$D and lab space


975
919B
919A
ERL and SCRF Facility
912
924
Beam Components Group
905
925
RF Stochastic Cooling Group
911
918
Power Supply Group


From Buildings 975 and 919 RTL
Existing building to be used for shielding storage
From Building 936 RTL (Completed)
Storage Consolidation
From Building 924 Renovate for Lab Space
From Building 918 Renovate for Lab Space
From Building 835 RTL (Completed)
(Return to Laboratory) RTL [for other use or demolition]

Summary and conclusions

- RHIC and injectors operations are running efficiently
- There is a plan in place to further improve operations performance (luminosity) and uptime (time at store, integrated luminosity)
- NECESSARY CONDITIONS for improvement:

  steady operations running, long runs (especially for polarized protons)

  investment in machine upgrades

  investment on infrastructures