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U.S. DEPARTMENT OF ENERGY

RHIC Performance Update

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Contents

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Collider-Accelerator Department Overview

Collider-Accelerator Department

- Mission: Design, develop, commission and operate state-of-the-art accelerators to carry out accelerator-based experiments in an environmentally responsible and safe manner. Perform accelerator R&D towards the next generation of accelerator facilities and accelerator applications in support of national needs.
- Presently ~360 FTE
- Significant legacy infrastructure issues (AGS started operation in 1960) are being addressed through continuous renovation and replacement of obsolete equipment.

User Facilities supported by C-AD

Collider-Accelerator Department Facilities

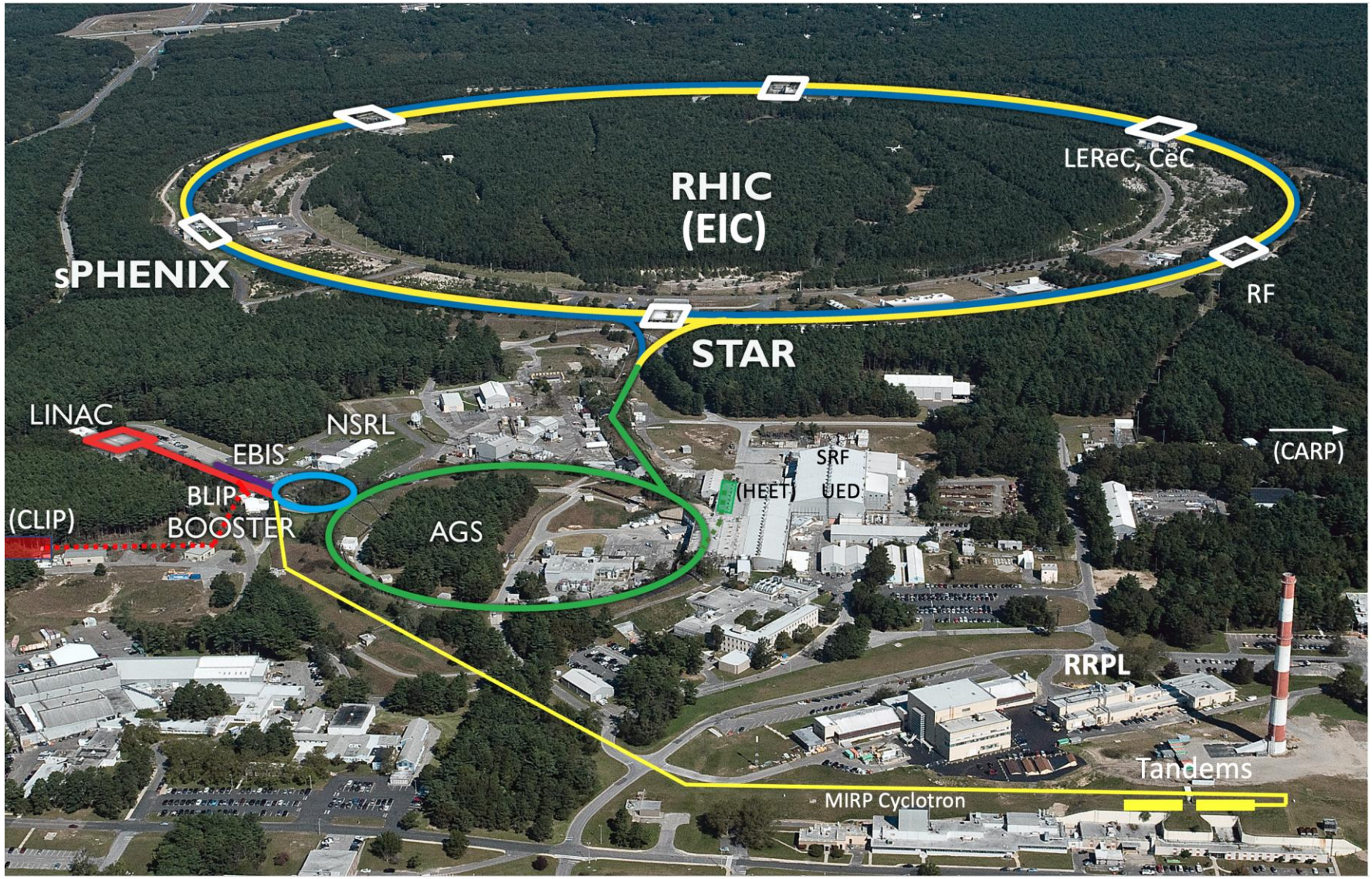
Uniquely flexible and only hadron collider in US for exploration of QCD phase diagram and proton spin

Injectors also used for application programs:

- Linac/BLIP for isotope production
- Booster/NSRL for space radiation studies
- Tandem for industrial/academic users

R&D for future facilities and application

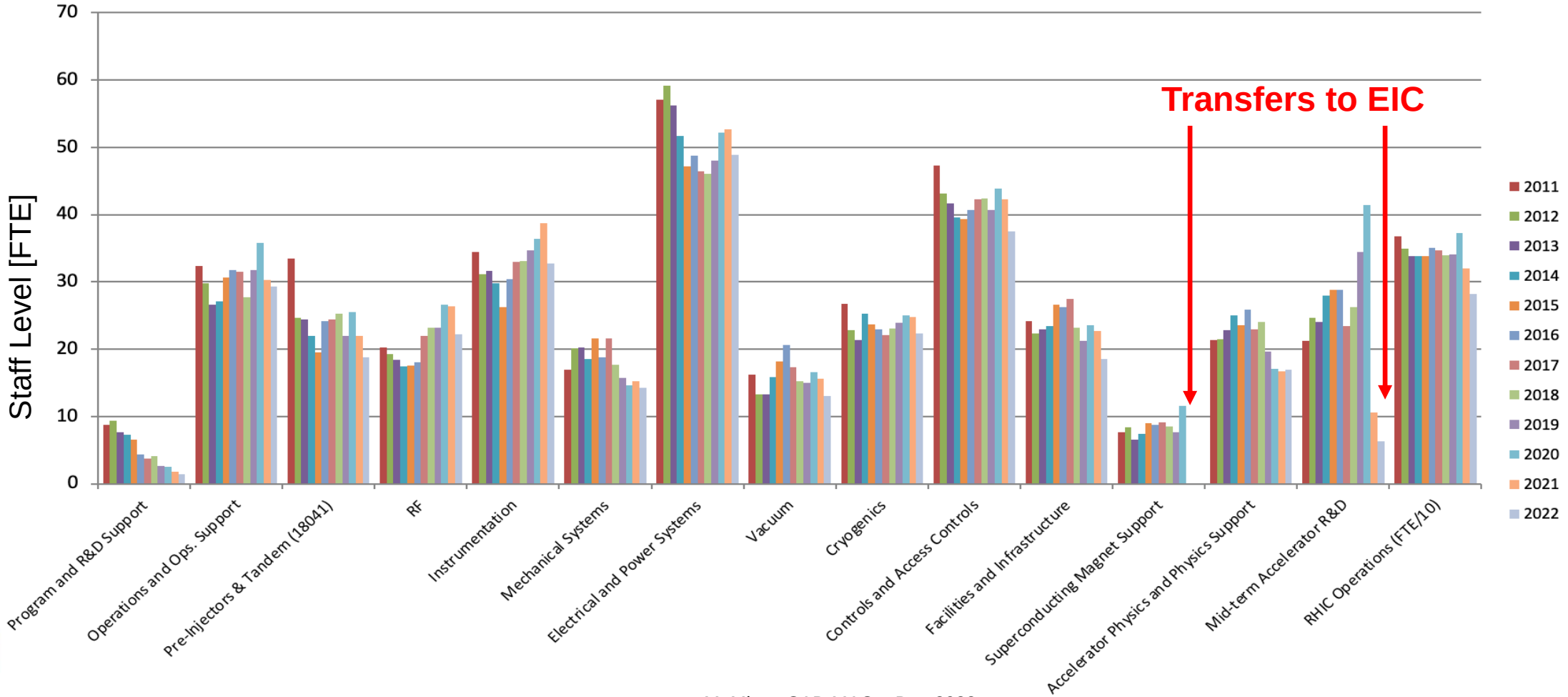
sources, cooling, pol. beams, …



RHIC Operations Staffing (Sep 2022)

C-AD based RHIC ops staff: 283 FTEs

- 20 FTEs of exp. support (PHENIX component redirected to sPHENIX)
- 15 FTE with MOU to EIC



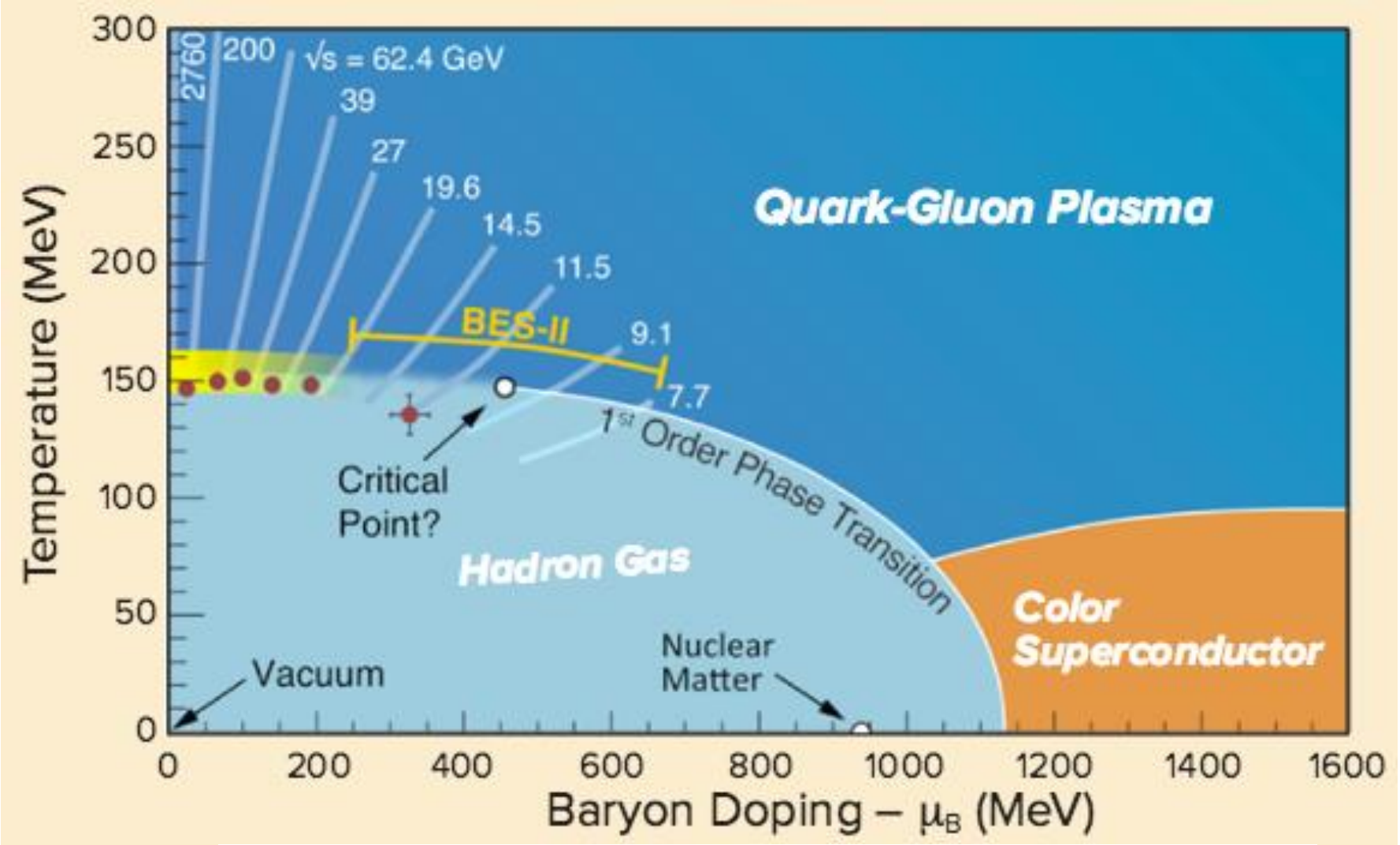
C-AD Demographics

- Age distribution of accelerator staff is of concern
- Expect significant number of retirements of over next decade, particularly in
  - technical staff
  - professional staff
- Also, an opportunity for changing the workforce
- Previous years allowed for new hires and knowledge transfer
- In addition to new hires, workforce changes due to career transition (e.g., MCR to engineering, AP, ESSHQ)

Recent RHIC Run Performance

Beam Energy Scan (BES) Program

BES-I: 2010 - 2011, 2014
BES-II: 2018 - 2020



From 2015 NSAC Long Range Plan for Nuclear Science

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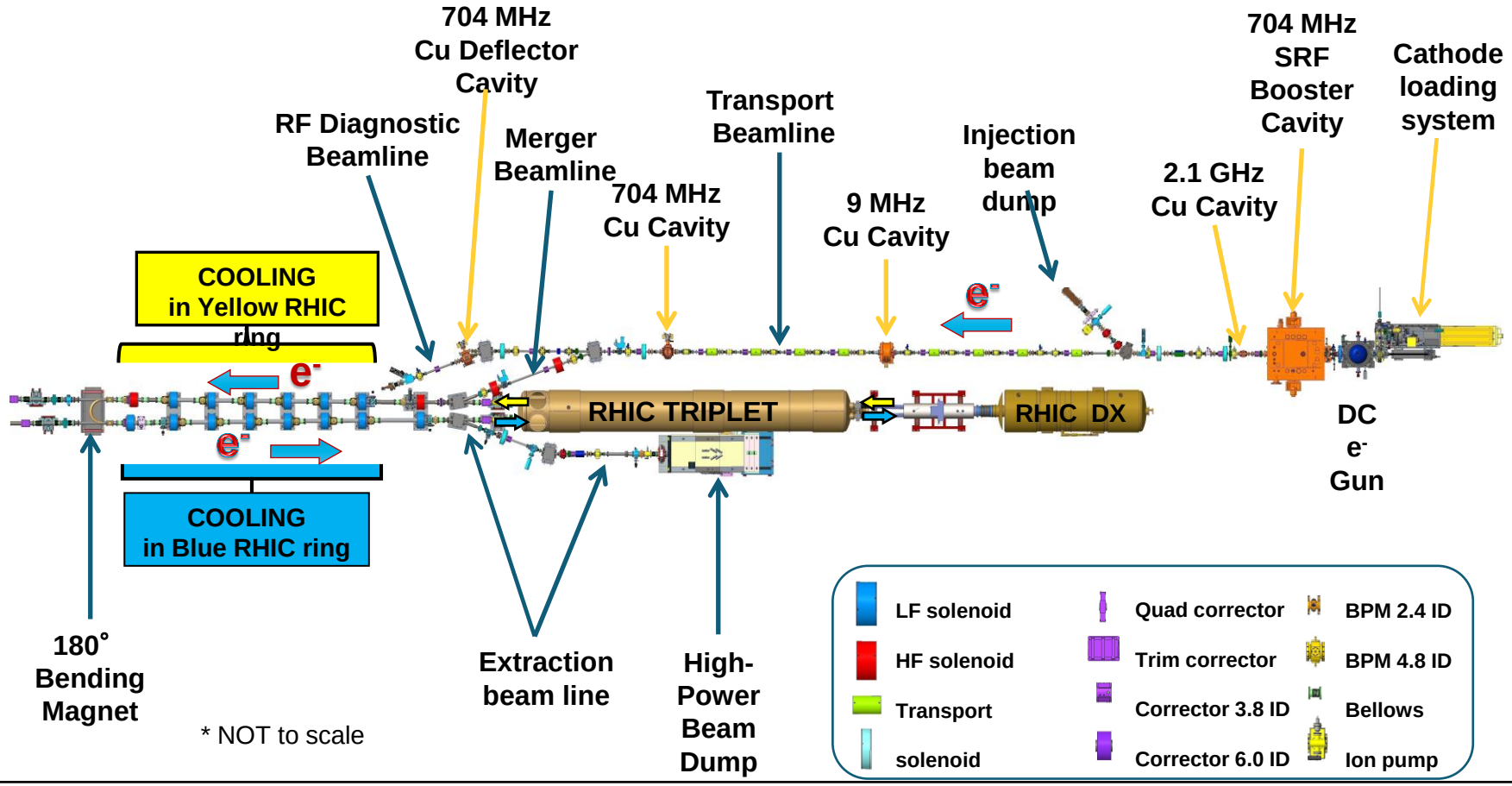
Low Energy RHIC electron Cooling (LEReC)

Principle Investigator
Alexei Fedotov



Technologies

- DC gun
- high QE cathodes
- high-power fiber laser
- 5 RF systems, including one SRF
- machine protection
- many magnets
- instrumentation
- 100 meters of beamlines

A. Fedotov et al, *Experimental Demonstration of Hadron Beam Cooling Using Radio-Frequency Accelerated Electron Bunches*, Physical Review Letters **124**, 084801 (Feb 2020).

First operational electron cooling in a collider (Run-20)
Critical for lowest-energy RHIC program in Run-21

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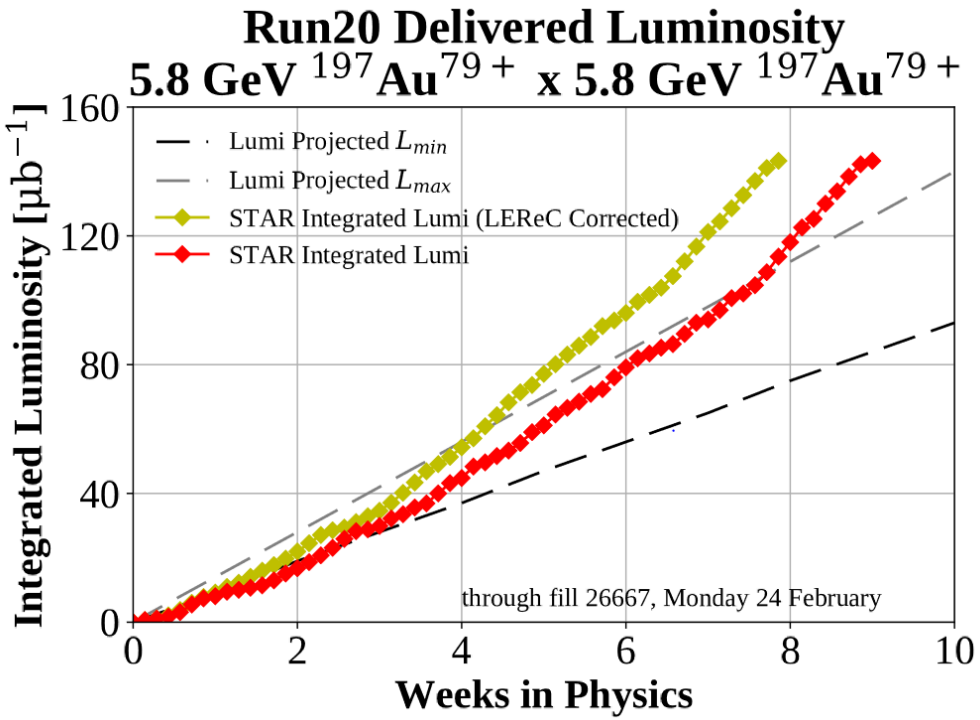
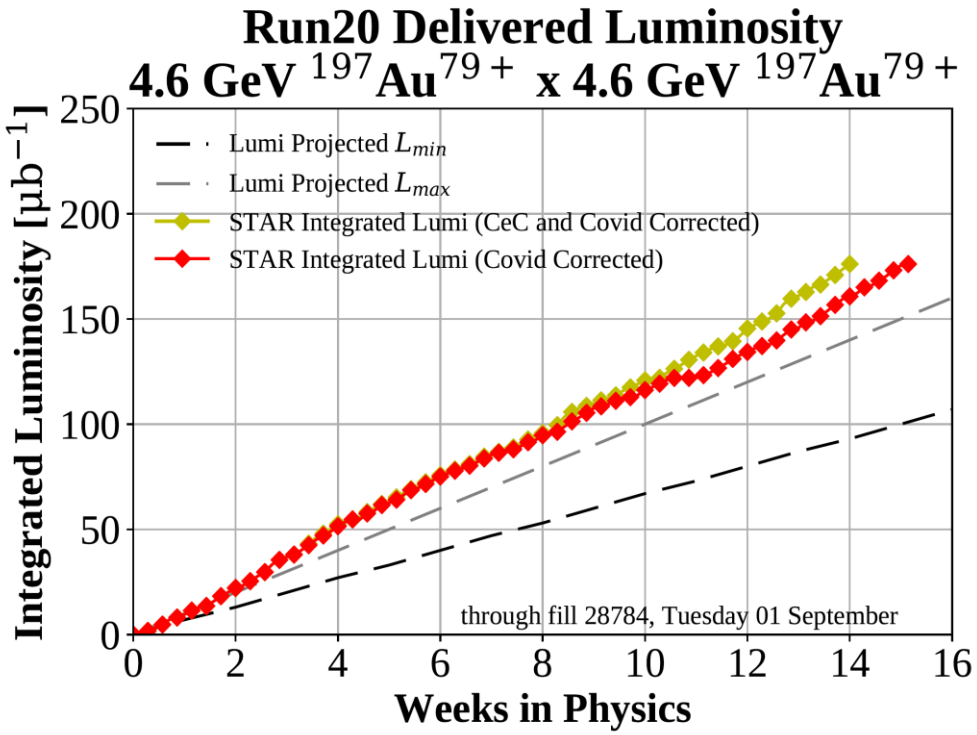
RHIC Run-20 – first operational use of LEReC

First demonstration of high-energy electron cooling
First application of electron cooling in a collider

Run Coordinator: Chuyu Liu (Run-19 to 21)
LEReC Principal Investigator: Alexei Fedotov





All Run-20 goals achieved or exceeded

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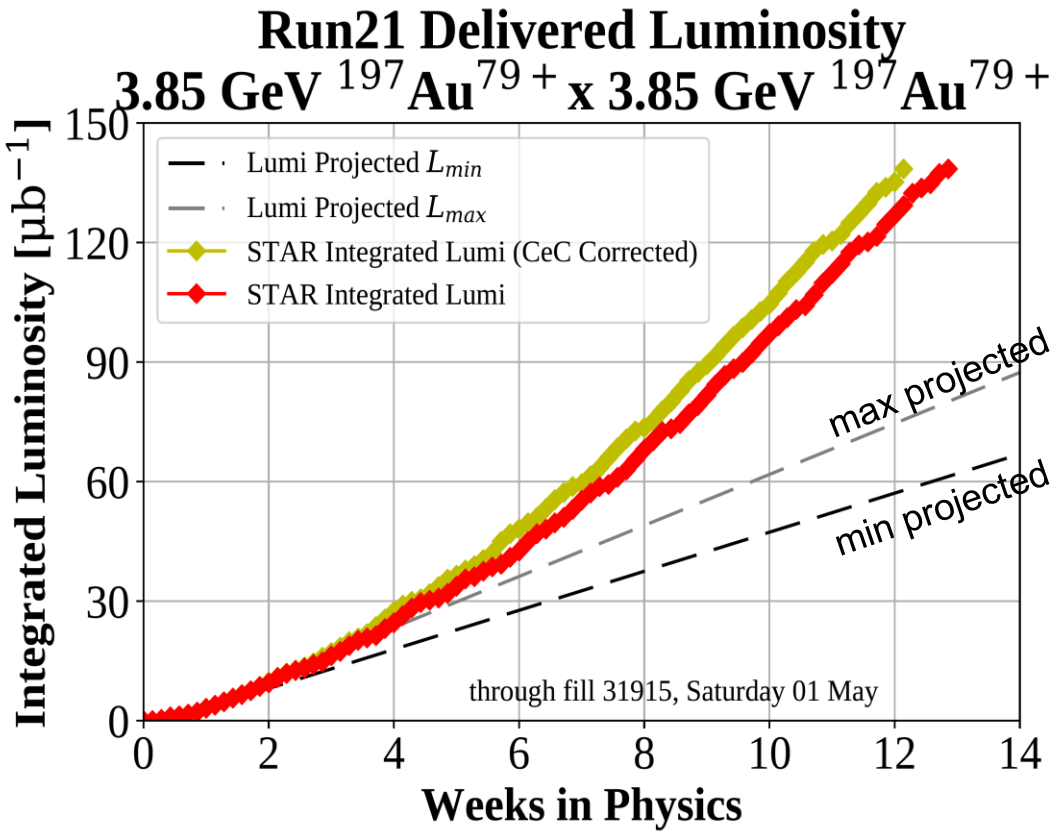
RHIC Run-21 – highest priority for BES-II

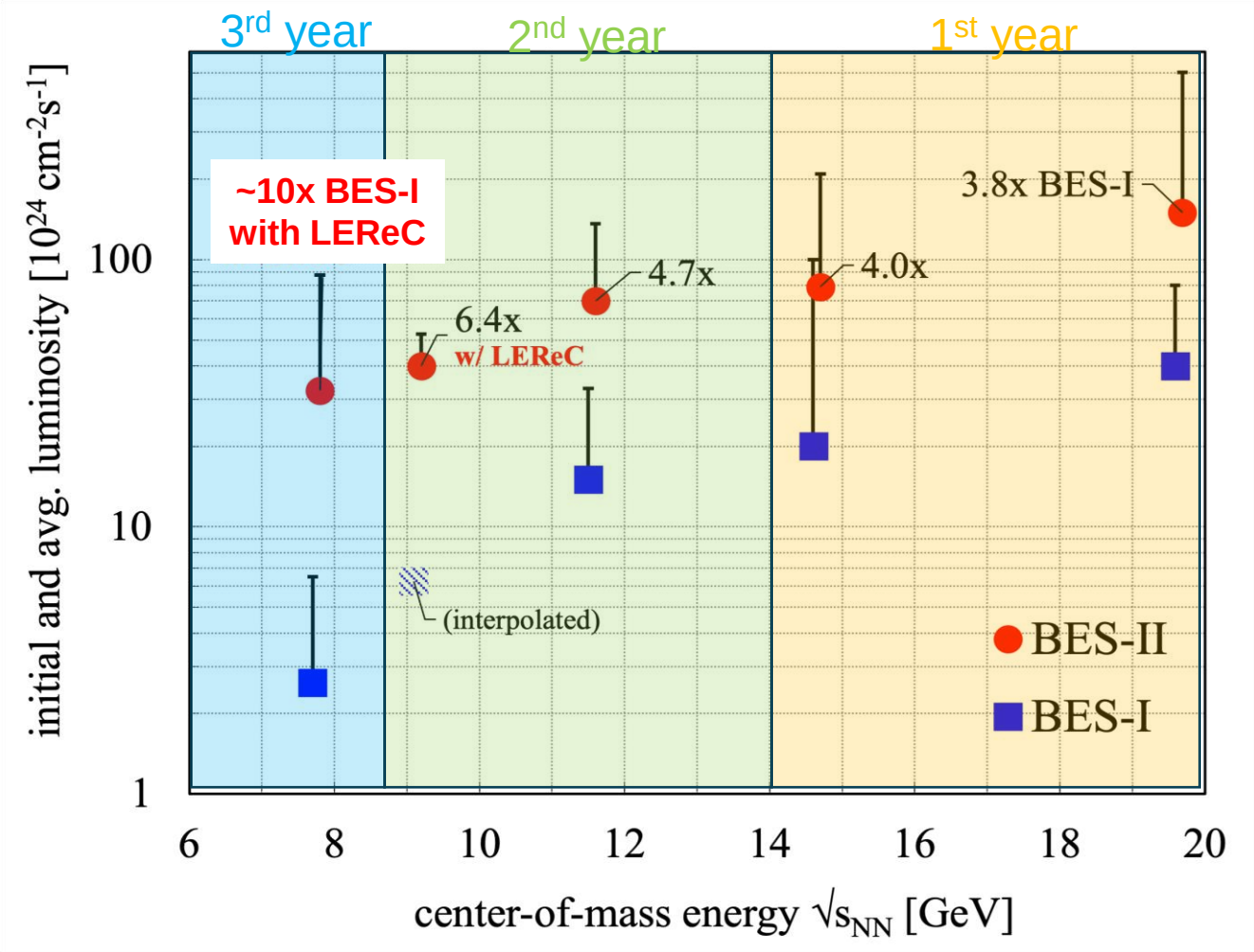
Second year with low-energy electron cooler (LEReC)
Most difficult energy (~40% lower than nominal injection energy)

Run Coordinator: Chuyu Liu (Run-19 to 21)
LEReC Principal Investigator: Alexei Fedotov



Highest priority Run-21 goal significantly exceeded

BES-I vs BES-II luminosity



Goal was L_{avg} (BES-II) = 4x L_{avg} (BES-I)

In BES-II

1st year	3.8 x L_{avg} (BES-I) 4.0 x L_{avg} (BES-I)	
2nd year	4.7 x L_{avg} (BES-I) 6.4 x L_{avg} (BES-I) ←	with LEReC
3rd year	~10 x L_{avg} (BES-I) ←	at lowest beam energies

Successful completion of the multi-year BES program

RHIC Run-22 – last full energy p↑+p↑ run at RHIC

Run coordinator: Vincent Schoefer

p↑+p↑ polarized proton collisions at 508 GeV c.o.m. with new STAR forward detector upgrade

Schedule

final cooldown to 4K delayed by 13 days
14 day run extension granted by DOE Office of NP

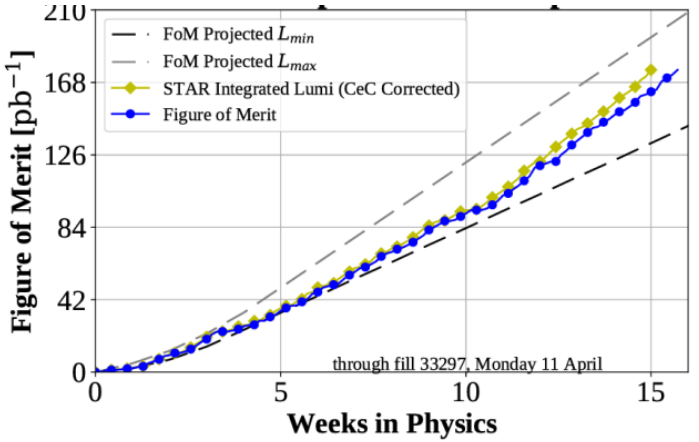
(Unusual) run challenges

two snake magnets damaged (power outage)
extended running with AGS Westinghouse motor generator

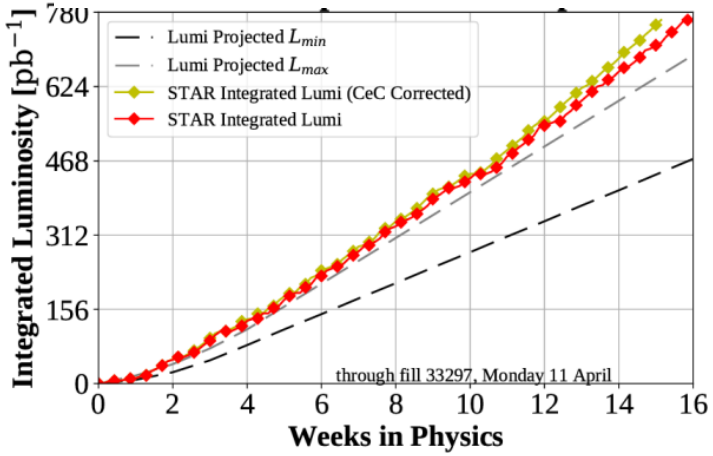
Performance summary

forward program: 107%, exceeding the goal
mid-rapidity: ~98%, achieving the goal

Run-22 delivered figure of merit



Run-22 delivered luminosity



Successful completion of last full energy polarized proton run

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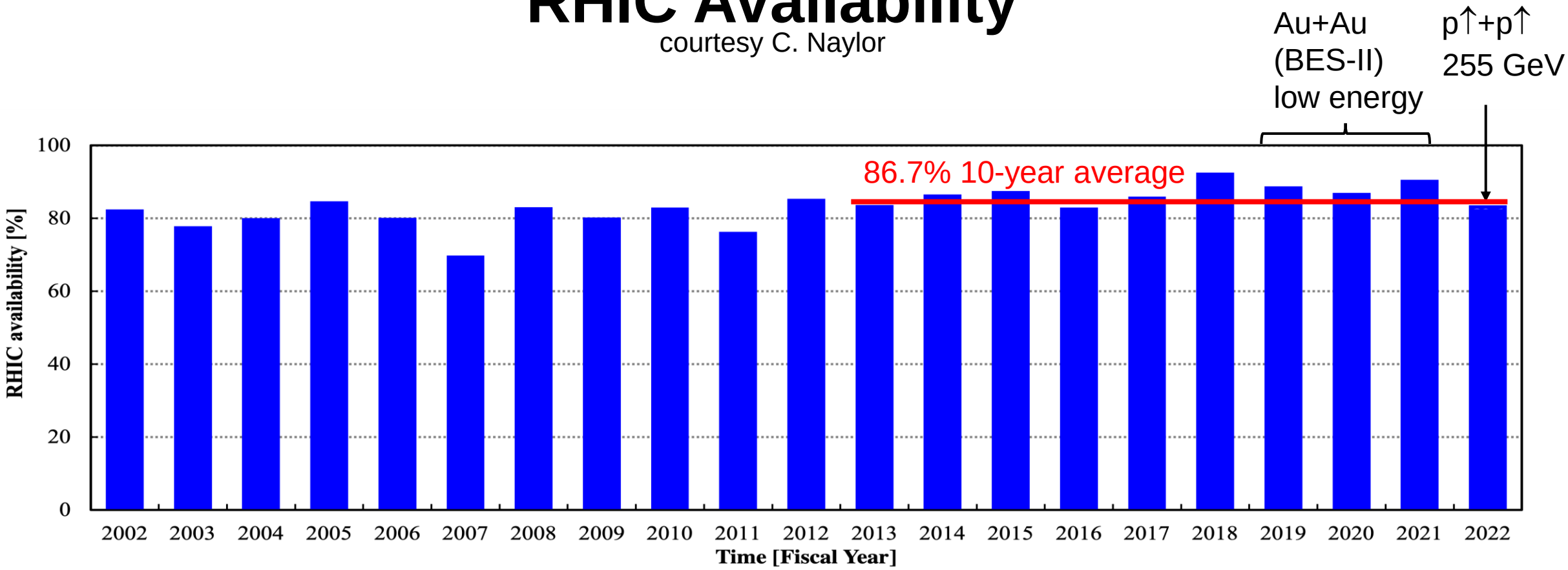
RHIC Availability

courtesy C. Naylor



Availability = beam time / scheduled beam time

(denominator excludes scheduled maintenance)

Availability goal: 85% (raised in FY20, from 82.5%)

>85% availability achieved averaged over last 10 years

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RHIC runs 2023 - 2025

RHIC Run Scenarios 2023 – 2025

Year	Scenario 1	Scenario 2
2023	24 cryo-weeks with sPHENIX and STAR Au+Au at 200 GeV	28 cryo-weeks with sPHENIX and STAR Au+Au at 200 GeV
2024	24 cryo-weeks with sPHENIX and STAR $p^{\uparrow}+p^{\uparrow}$ and $p^{\uparrow}$+Au at 200 GeV	28 cryo-weeks with sPHENIX and STAR $p^{\uparrow}+p^{\uparrow}$ and $p^{\uparrow}$+Au at 200 GeV
2025	24 cryo-weeks with sPHENIX and STAR Au+Au at 200 GeV	28 cryo-weeks with sPHENIX and STAR Au+Au at 200 GeV

- Experiments make beam use requests
- Program Advisory Committee provides recommendations for RHIC run priorities
- Number of running/cryo-weeks depends on the annual budget normally
- Runs 2023-2025 are unique: new detector sPHENIX coming online & EIC construction/access RHIC tunnel starts in 2025

Opportunistic fixed target run during Run 23-25 is under development, which is important for NASA

Challenges: the remaining calendar weeks in FY23, and the overall tight schedule to complete the sPHENIX science goals

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Reliability - operation during summer months

Concerns	Heat	Many support buildings not equipped to operate with sustained high temperatures Many unique AC systems
	Humidity	Reduced cooling tower efficiency, increased load on AC equipment Condensation issues
	Power	More frequent power dips and/or outages (storm related), possible brown-outs
	Air Conditioning	Aging equipment, some obsolete controls and parts

Mitigation

Maintenance

- ensure existing systems are operable at full capacity
- verify existing AC spares inventory (9 portable units, 6 portable high-volume fans)

AC ductwork modifications

New procurements

- spare AC systems for RHIC alcoves (5)
- portable AC units for RHIC service buildings (6) for power supply quench detection racks

Reliability - injector complex

LINAC

RF power amplifiers - continuing to maintain a 5-year inventory

Transitioned (completed in 2019) from person-based to group-based operational support by transfer of responsibilities to C-AD support groups

LINAC / AGS

Increased detail in shutdown schedule management lately as time available for maintenance becoming shorter with expanding user programs at MIRP (isotope production) and NSRL (NASA)

AGS

Motor generators (MG) – Siemens MG and back-up Westinghouse MG with 40+ and 60+ years in operation, respectively: coordinating closely with new companies (TECO Westinghouse, Industrial Power Systems, and ABB)

Note: accelerator readiness reviews are needed for these (existing) facilities

Reliability – infrastructure upgrades

Select BNL Science Lab Initiatives (SLIs)

1) Critical Utilities Rehabilitation Project, CURP (FY20 – FY26, $92M) – CD2/3 completed

Electrical distribution system upgrade including a new feeder to replace 60-year-old underground feeder and 13.8 kV switch gear

Steam distribution system upgrade (replace up to 3 central plan chillers, install an additional chilled water storage tank)

2) Critical Utilities Revitalization & Enhancement, CURE ($200-350M) – proposed

Replace or refurbish components of the original building electrical distribution equipment (all more than 50-years old switchgears, motor control centers, power panels and automatic transfer switches) to enhance operational safety and reliability in several facilities

Notes: compatibility and availability of spares a concern, however components are generally reliable upgrades improve safety during servicing

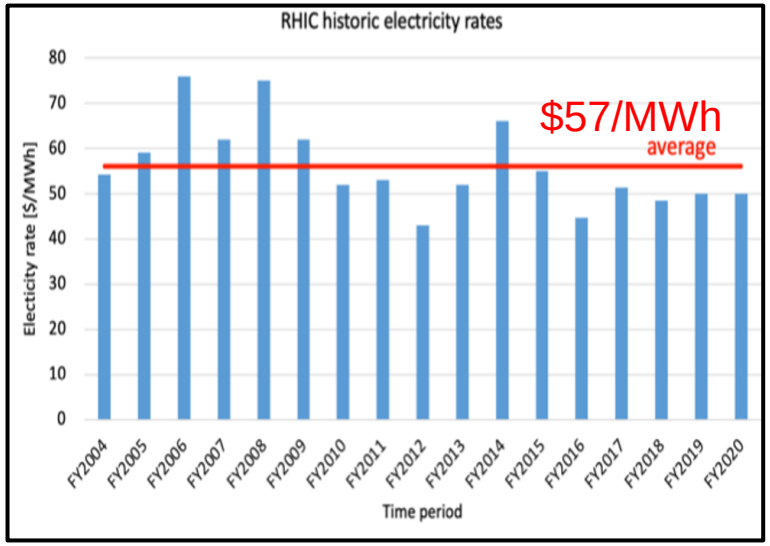
Other factors affecting operational reliability

Personnel retirements, relocations, and burnout – addressing with

- active hiring in close coordination with HR and recruiters
- training and (some) mentoring of new and existing workers
- improving documentation of procedures, workplans, project archiving

Electrical costs no fixed price contract, price volatility

- FY21: $41/MWh
- FY22: $61/MWh
- FY23: planning with $60/MWh



Cost of LHe BNL contract bid for $50/gallon

sole source quote received (Oct 27) for $77.4/gallon

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RHIC Snake Magnet – plan for Run-24

Dummy magnet installed and fully tested (leak-checked) for Run-23

Installation prior to Run-23 contingent on sPHENIX schedule and available workforce

Installation schedule estimate with early start

installation mechanical	~ 3 weeks
electrical testing	~ 3 weeks

Repair completion: March 23, 2023 (schedule detail in backup slides)
Repaired RHIC Snake Magnet will be ready for Run-24

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RHIC 25-year plan and cryo upgrade for the EIC

25+ Year Upgrade Plan

Manager: Rob Michnoff

Goals

maintain technical infrastructure

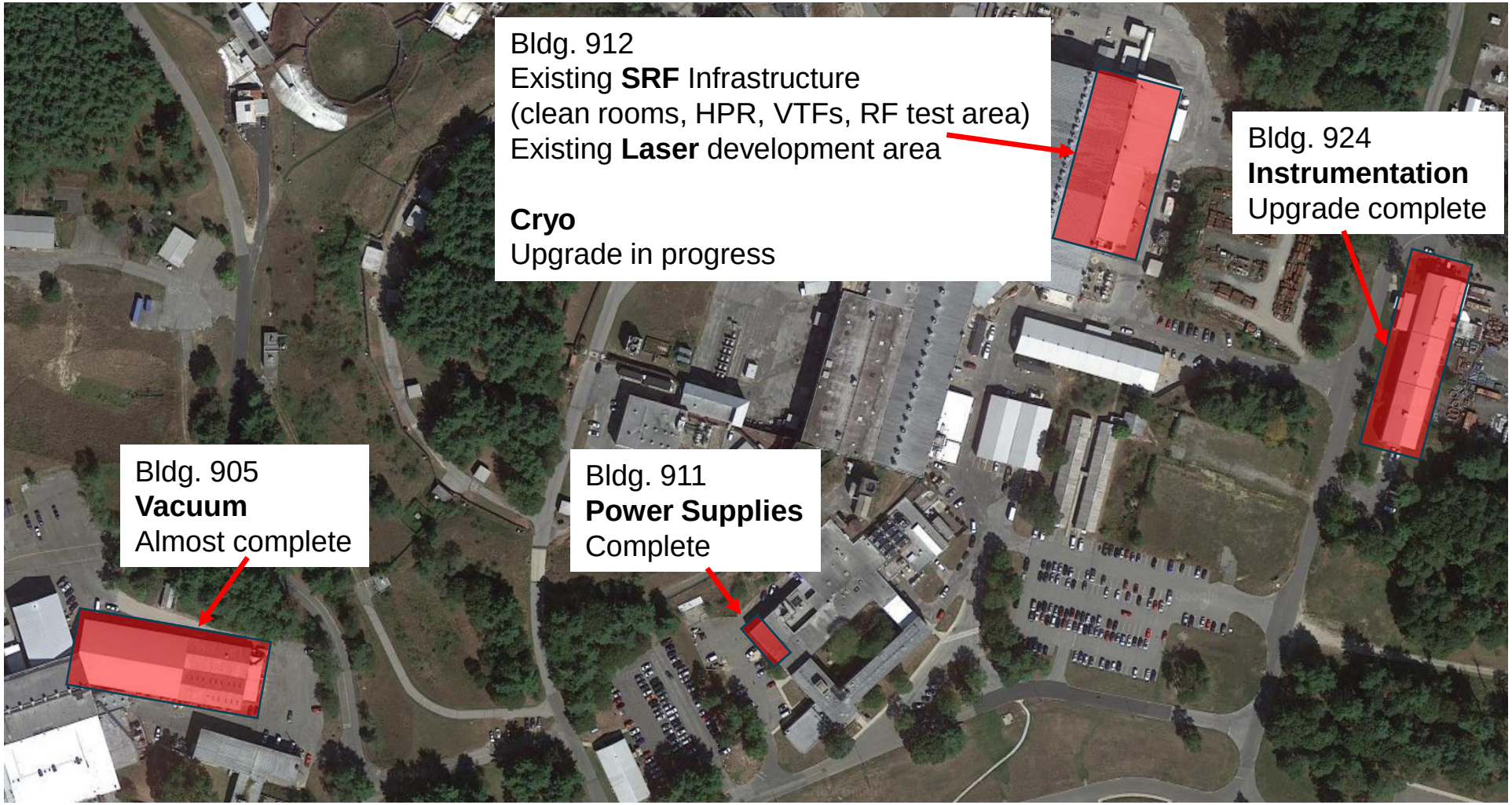
ensure hadron injector complex ready for EIC commissioning while also running for external users (NSRL and BLIP), and possibly HEET

ensure that system upgrades satisfy both short-term injector and RHIC needs as well as longer-term EIC requirements

- Initiated in 2018 for RHIC and the injector complex with considerations for the EIC
- Assessed periodically based on need for
  - performance upgrades
  - upgrades of obsolete systems
- Assumes no further large accelerator upgrades until the end of RHIC operations in 2025

Technical infrastructure upgrades

Building upgrades supported mostly by BNL, technical upgrades by C-AD



2018 – Evaluation of upgrade and infrastructure needs for RHIC+EIC Over Next 25+ Years

	(all numbers in $M)	Total cost with OH	RHIC Total	RHIC Ops	RHIC CE/AIP	EIC Total	EIC Ops	EIC CE/AIP
1	Buildings	0.8	0.8	0.8	0.0	0.0	0.0	0.0
2	Water Systems	4.9	2.2	1.1	1.1	2.7	1.0	1.7
3	Electric Power Distribution	16.6	9.2	2.0	7.2	7.4	0.2	7.2
4	Electrical Systems	42.0	37.1	15.3	21.8	4.9	0.8	4.2
5	Cryogenic Systems	23.9	23.9	2.4	21.5	0.0	0.0	0.0
6	Vacuum Systems	10.0	4.8	2.8	2.0	5.3	0.5	4.8
7	RF Systems	11.0	1.7	0.1	1.5	9.4	1.4	8.0
8	Instrumentation Systems	11.2	9.8	3.2	6.6	1.4	1.0	0.4
9	Controls Systems	32.3	12.1	8.4	5.9	20.2	6.3	13.9
10	Preinjector Systems	1.2	1.2	0.6	0.6	0.0	0.0	0.0
11	Other	0.1	0.0	0.0	0.0	0.1	0.0	0.1
	Total cost	**154.2**	**102.8**	**36.9**	**68.2**	**51.4**	**11.1**	**40.2**
	Annual cost	**6.1**						
	Expected annual funding	5.5	5.5	2.0	3.5	5.5	2.0	3.5

← Paid in part by lab infrastructure funding

← Largest medium-term need

Update in progress

Costs initially sorted into funding streams (eventually assumed by EIC)
C-AD labor not included (historically used ~25 FTE for upgrades)

Some large items (e.g. Booster MMPS $11.5M, Booster transformers $4.8M) not captured in present funding plan

Present plans call for use of all AIP funds to support cryogenic system upgrades

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AIP and CE Funding plan (FY2021-2028) - updated 2022 LMBB scenario 1

Description	FY21	FY22	FY23 Est.	FY24 Est.	FY25 Est.	FY26 Est.	FY27 Est.	FY28 Est.
CE								
RHIC Access Control System upgrade	$ 800							
AGS beam position monitor electronics upgrade	$ -	$ 800	$ 100					
Chipmunks upgrade	$ -	$ -	$ 800	$ 100				
RHIC cryo corrector flowmeters upgrades	$ -	$ -	$ -	$ 800	$ 200			
Replacement of AGS corrector power supplies	$ -	$ -	$ -	$ -	$ 800	$ 1,000	$ 200	
Water tower #7 replacement	$ -	$ -	$ -	$ -	$ -	$ -	$ 800	$ 1,000
TOTAL FACILITY BASE CE	**$ 800**	**$ 800**	**$ 900**	**$ 900**	**$ 1,000**	**$ 1,000**	**$ 1,000**	**$ 1,000**
AIP								
Bldg. 912 technical infrastructure upgrade (cryo)								
AGS Siemens cycloconverter upgrade	$ 500	$ 2,500	$ 500					
Cryo upgrade phase 1	$ -	$ -	$ 1,600	$ 2,100	$ 2,000			
Cryo upgrade phase 2	$ -	$ -	$ -	$ -	$ -	$ 2,000	$ 2,000	$ 1,900
TOTAL AIP	**$ 500**	**$ 2,500**	**$ 2,100**	**$ 2,100**	**$ 2,000**	**$ 2,000**	**$ 2,000**	**$ 1,900**

Availability goal raised from 82.5% to 85% 2 years ago
Booster Main Magnet Power Supply upgrade not presently funded by AIP
CE completed before end of FY2025 and AGS cycloconverter upgrade would still benefit RHIC

Majority of AIP funding needed for cryo upgrades, not sufficient for completion before EIC commissioning starts (cryo upgrades would continue beyond FY2028)

[Note: AIPs can only start with all funding in hand]

AIP and CE Funding plan (FY2021-2028) - 2022 LMBB scenario 2

Description	FY21 Est.	FY22 Est.	FY23 Est.	FY24 Est.	FY25 Est.	FY26 Est.	FY27 Est.	FY28 Est.
CE								
RHIC Access Control System upgrade	$ 800							
AGS beam position monitor electronics upgrade	$ -	$ 900						
Chipmunks upgrade	$ -	$ -	$ 900					
RHIC cryo corrector flowmeters upgrades	$ -	$ -	$ -	$ 1,000				
Replacement of AGS corrector power supplies	$ -	$ -	$ -	$ -	$ 1,000	$ 1,000		
Water tower #7 replacement	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,000	$ 1,100
TOTAL FACILITY BASE CE	**$ 800**	**$ 900**	**$ 900**	**$ 1,000**	**$ 1,000**	**$ 1,000**	**$ 1,000**	**$ 1,100**
AIP								
Bldg. 912 technical infrastructure upgrade (cryo)								
AGS Siemens cycloconverter upgrade	$ 500	$ 2,500						
Cryo upgrade phase 1	$ -	$ 200	$ 4,000	$ 6,000				
Cryo upgrade phase 2	$ -	$ -	$ -	$ -	$ 6,000	$ 6,000		
Cryo upgrade phase 3	$ -	$ -	$ -	$ -	$ -	$ -	$ 6,000	$ 6,000
TOTAL AIP	**$ 500**	**$ 2,700**	**$ 4,000**	**$ 6,000**	**$ 6,000**	**$ 6,000**	**$ 6,000**	**$ 6,000**

Availability goal raised from 82.5% to 85% 2 years ago
Almost same plan for Capital Equipment as for Scenario 1
CE completed before end of FY2025 and AGS cycloconverter upgrade would still benefit RHIC

Alternative funding resources requested to complete cryo upgrades before the EIC

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Cryo upgrade detail

Bldg 912 SRF test facility

new Cryo Plant: $7M available in the AIP bank for major procurements
received quotes for planned work significantly higher than expected – coordinating to reduce scope

Phase 1 upgrade: main 4K Plant

oil skids, intercoolers/aftercoolers, ambient vaporizers

Phase 2 upgrade: main 4K Plant

cold end (10K-4.5K) heat exchanger and expander 7

Phase 3 upgrades for reduction in Helium consumption

main 4K plant: replace mechanical joints and flanged warm valves with welded joints

collider ring: replace current lead return circuits and valve box fittings with welded joints

more urgent now: 7%/year price increase over 15 years; significant increase last year

Response to Recommendation from C-AD MAC 2021

Recommendation: Perform an assessment of components and spares needed to continue running in the EIC era

The EIC does not place additional requirements on the (hadron) injectors

LINAC/Booster/AGS

- oversight of component spares continue to be maintained by support groups
- LINAC/Booster will continue to operate in support of user programs
- AGS may operate if HEET facility is funded

Spares for the new electron accelerators (Rapid Cycling Synchrotron and Electron Storage Ring) are the purview of the EIC Project

For the EIC Hadron Storage Ring, multiple superconducting magnets will be available

Summary

Summary

RHIC runs – 3 years solid and successful performance

- RHIC run performance (Runs 19-21) – completion of the BES-II program with LEReC
  - successful (beyond expectation) demonstration of high-energy electron beam cooling
  - first-ever utilization of high-energy electron beam cooling in a collider
  - completion of multi-year beam energy scan program
- RHIC Run-22 - last run with full energy polarized proton collisions
  - with 2-week extension, goals met despite challenges (RHIC Blue Ring Siberian Snake, extended operation with AGS backup motor generator)

Reliability challenges in upcoming runs

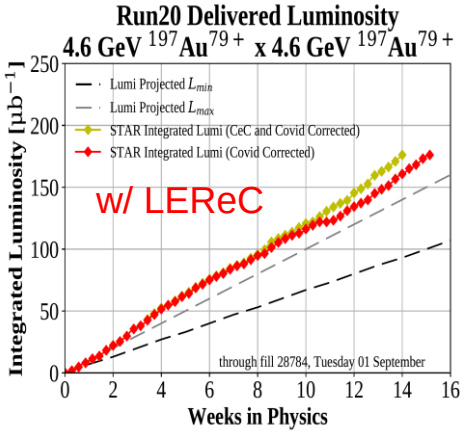
- proactively addressing concerns about operation through summer months
- emergent increase in electricity and helium costs
- challenged by dynamically changing workforce (presentation by W. Fischer)

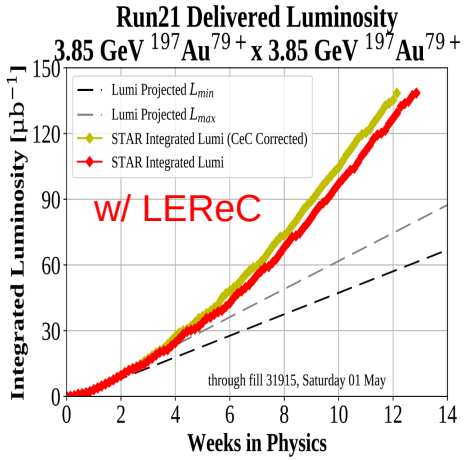
RHIC Blue Snake magnet repair and mitigation plan for Run 2024

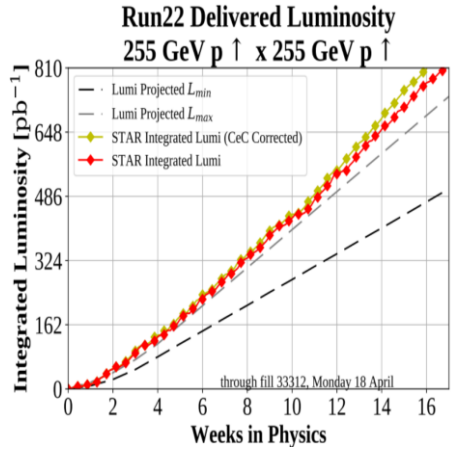
- repairs to be completed March, 2023
- dummy magnet in place for Run-23, installation prior to Run-23 TBD
- expected to be ready for run-24

Ongoing and planned AIP and CE projects including RHIC 25-year plan and cryo upgrade

- all AIP funds are planned to be spent on cryo upgrades
- cryo upgrades will likely continue beyond FY28 with present level of AIP funding
- alternative funding resources needed to complete main cryo upgrades







Backup Slides

LEReC summary for 2020

- 3-D cooling was commissioned and optimized using 2 MeV electron beam for Physics operation at $\sqrt{s_{NN}}$ = 9.2 GeV**.**
- First operational electron cooling in a collider (cooling of ion beams in collisions and luminosity optimization with cooling) was established.
- Stable 24/7 running of high-current electron accelerator over many weeks.
- Cooling was made operational, including implementation of laser position feedback, intensity feedback, energy feedback, automatic cooling section orbit corrections and feedback.
- Controls of LEReC accelerator was transferred to the MCR operations, with support by LEReC experts when needed.
- Five LEReC peer-review articles were published (see listing in reference slides): one **Phys Rev Letters** and four Phys Rev Accel Beams papers, including two which were selected as “Editors’ suggestion”.
- Alexei Fedotov received 2019 Brookhaven Science and Technology Award with citation of world’s first “demonstration of bunched beam electron cooling”

Beam Energy Scan II scoreboard

Beam Energy (GeV/nucleon)	$\sqrt{s_{NN}}$ (GeV)	μ_B (MeV)	Run Time	Number Events Requested (Recorded)	Date Collected
13.5	27	156	24 days	(560 M)	Run-18
9.8	19.6	206	36 days	400 M (582 M)	Run-19
7.3	14.6	262	60 days	300 M (324 M)	Run-19
5.75	11.5	316	54 days	230 M (235 M)	Run-20
4.59	9.2	373	102 days	160 M (162 M)[1]	Run-20+20b
31.2	7.7 (FXT)	420	0.5+1.1 days	100 M (50 M+112 M)	Run-19+20
19.5	6.2 (FXT)	487	1.4 days	100 M (118 M)	Run-20
13.5	5.2 (FXT)	541	1.0 day	100 M (103 M)	Run-20
9.8	4.5 (FXT)	589	0.9 days	100 M (108 M)	Run-20
7.3	3.9 (FXT)	633	1.1 days	100 M (117 M)	Run-20
5.75	3.5 (FXT)	666	0.9 days	100 M (116 M)	Run-20
4.59	3.2 (FXT)	699	2.0 days	100 M (200 M)	Run-19
3.85	3.0 (FXT)	721	4.6 days	100 M (259 M)	Run-18
3.85	7.7	420	11-20 weeks	100 M	Run-21[2]

all Run-20 goals achieved or exceeded

RHIC Run-21 – completion of entire beam use request

Single-Beam Energy (GeV/nucleon)	$\sqrt{s_{NN}}$ (GeV)	Run Time	Species	Events (MinBias)	Priority	
3.85	7.7	11-20 weeks	Au+Au	100 M	1	✓
3.85	3 (FXT)	3 days	Au+Au	300 M	2	✓
44.5	9.2 (FXT)	0.5 days	Au+Au	50 M	2	✓
70	11.5 (FXT)	0.5 days	Au+Au	50 M	2	✓
100	13.7 (FXT)	0.5 days	Au+Au	50 M	2	✓
100	200	1 week	O+O	400 M 200 M (central)	3	✓
8.65	17.3	2.5 weeks	Au+Au	250 M	3	✓
3.85	3 (FXT)	3 weeks	Au+Au	1.7 B	3	✓
100	200		d+Au	100 M 100 M (central)	4	✓

- Highest priority FY21 goal for BES-II achieved with LEReC in 13 weeks.
- Met all next-priority STAR goals including an additional d+Au run (8 modes + beam delivery for CeC).
- Missions achieved with limited on-site staff and full off-site coverage during the COVID pandemic.

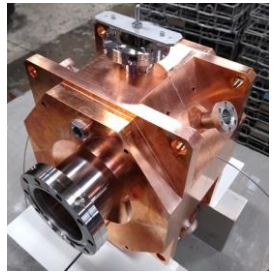
All Run-21 goals achieved or exceeded + additional d+Au run

Highlights from FY21 BES-II program with LEReC

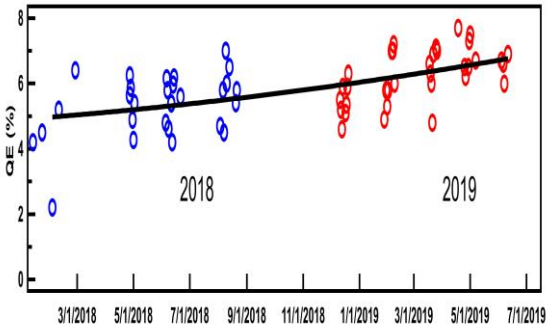
Run Coordinator: Chuyu Liu

- Operated 24/7 high-current electron beams with stable cooling at lowest-ever, and most challenging, RHIC beam operating energy (3.85 GeV/n) in FY21 Run.
- All performance goals attained. Additional operational improvements implemented:
  - New LEReC 1.4 GHz cavity and new RHIC bunch-by-bunch dampers
  - Feedback-based beam control for electron orbits in cooling sections, electron beam energy, electron beam intensity and laser position feedback.
  - Utilization of existing 3rd harmonic (28 MHz) cavity in RHIC to reduce ion beam peak current
  - Optimization of electron beam currents based on operational experience
    - 15-20 mA (for Au ions at 4.6 GeV/n in 2020)
    - 8-20 mA (for Au ions at 3.85 GeV/n in 2021)

1.4 GHz cavity



- Select demonstrated additional technological advances:
  - Robust photocathodes with high initial Quantum Efficiency
  - Photocathode lifetimes of 6-10 days
  - Stable and reliable operation of high-power fiber laser for photoelectron gun



With LEReC, the highest-priority goal of the BES-II program was successfully completed in FY21 in ~ 13 weeks.

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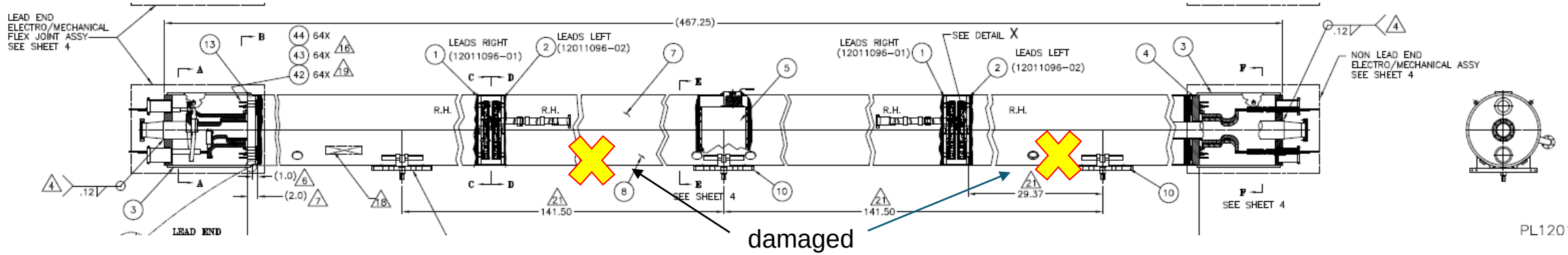
RHIC Blue Snake Magnet



Two Snake magnets damaged during Run-22 (12/3/21, 12/12/22)

During Run-22

- all 4 spare magnets tested at SC Magnet Division (SMD)
- prepared plans for repair (SMD and C-AD)
- Gary McIntyre (C-AD, retired) hired as consultant

During and after RHIC run

- one spare magnet appropriately reconfigured (SMD)

After RHIC run

- extensive electrical testing and training (C-AD electrical systems group)
- transported to SMD for repair (6/6/22), next slides

Note: plan for Run-23 is Au+Au (unpolarized), snake magnet needed for Run-24 ($p^{\uparrow}+p^{\uparrow}$)

RHIC Snake Magnet - repair details

M. Anerella (SMD)

Work completed

- ✓ 1 Spare Storage Unit
  - ✓ reworked to correct configuration
  - ✓ Hung on top hat and is being wired for cold test
- ✓ 1 Spare Storage Unit
  - ✓ Electrically tested & ready for magnet assembly
- ✓ Magnet Disassembly
  - ✓ Cold mass, heat shields removed from cryostat
  - ✓ Cold mass disassembly nearly complete
    - ✓ End volumes, bus work removed
    - ✓ Helium vessel shells cut off
    - ✓ Cold mass reinstalled onto assembly fixture

Work remaining

- Cold test 1 Storage Unit
- Remove beam pipe / BPM assembly
- Remove storage units from assembly fixture & replace with spares
- Complete cold mass assembly & pressure/leak check test
- Complete cryostatted magnet assembly






Repair completion: March 3 , 2023 (schedule detail in backup slides)

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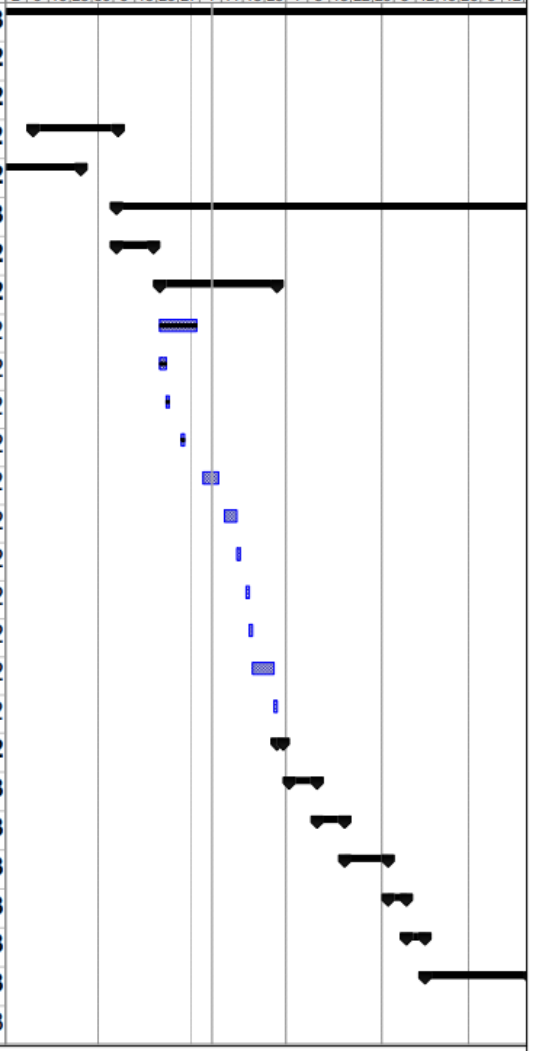
RHIC Snake Magnet - repair schedule

M. Anerella (SMD)

RHIC Helical Magnet Schedule
Return from Ring and Repair

ID	Task Name	Duration	Start	Finish
1	**RHIC Snake Repair**	**257 days**	**Tue 3/15/22**	**Tue 3/21/23**
2	**Spare Storage Unit Testing (2)**	**48 days**	**Tue 3/15/22**	**Thu 5/19/22**
6	**Spare Storage Unit Conversion (1)**	**70 days**	**Fri 5/20/22**	**Tue 8/30/22**
25	**Cold Test (1)**	**19.5 days**	**Tue 10/11/22**	**Mon 11/7/22**
44	**Disassembly**	**98.5 days**	**Mon 6/6/22**	**Wed 10/26/22**
84	**Reassembly / Shipment**	**93 days**	**Mon 11/7/22**	**Tue 3/21/23**
85	**Storage Unit Positioning**	**9 days**	**Mon 11/7/22**	**Fri 11/18/22**
92	**Shell Welding**	**25 days**	**Mon 11/21/22**	**Wed 12/28/22**
93	weld/leak check/hypot lower shell assembly	8 days	Mon 11/21/22	Fri 12/2/22
94	partial heater wiring	2 days	Mon 11/21/22	Tue 11/22/22
95	install bus conduits	1 day	Wed 11/23/22	Wed 11/23/22
96	tack backup strips to yokes	1 day	Mon 11/28/22	Mon 11/28/22
97	tack weld lower shell	5 days	Mon 12/5/22	Fri 12/9/22
98	connect power leads, voltage taps	4 days	Mon 12/12/22	Thu 12/15/22
99	electrical testing	1 day	Fri 12/16/22	Fri 12/16/22
100	partial wiring of warmup htrs	1 day	Mon 12/19/22	Mon 12/19/22
101	install conduits	1 day	Tue 12/20/22	Tue 12/20/22
102	weld shells	4 days	Wed 12/21/22	Tue 12/27/22
103	weld BPM stack	1 day	Wed 12/28/22	Wed 12/28/22
104	**End Plate Assembly**	**2 days**	**Thu 12/29/22**	**Fri 12/30/22**
106	**E/M Assembly**	**7 days**	**Mon 1/2/23**	**Tue 1/10/23**
113	**End Volume Assembly**	**7 days**	**Wed 1/11/23**	**Thu 1/19/23**
117	**Cradle Assembly**	**10 days**	**Fri 1/20/23**	**Thu 2/2/23**
123	**Alignment Measuring**	**4 days**	**Fri 2/3/23**	**Wed 2/8/23**
126	**Pressure Leak Checking**	**4 days**	**Thu 2/9/23**	**Tue 2/14/23**
128	**Cryostat Assembly**	**24 days**	**Wed 2/15/23**	**Mon 3/20/23**
134	Ship to Ring	0 days	Tue 3/21/23	Tue 3/21/23



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