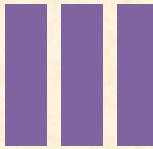




Looking to the Future

Frank Geurts
Rice University



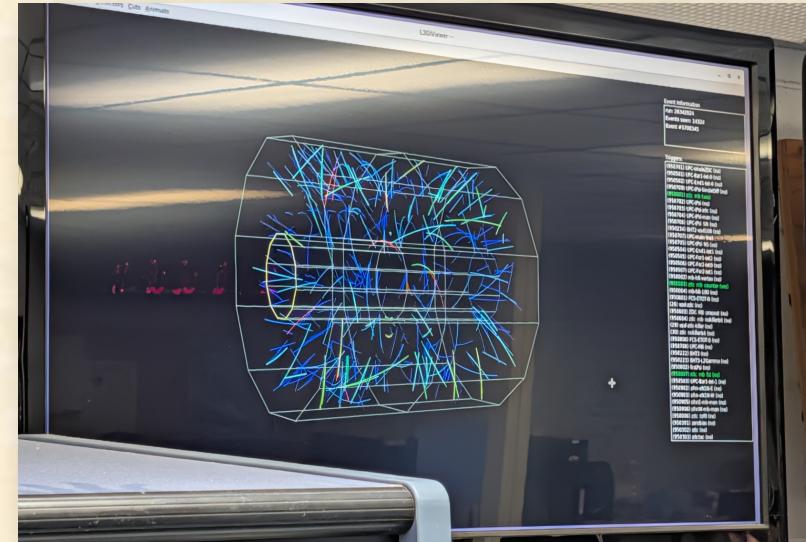
Looking back

- From First Collisions

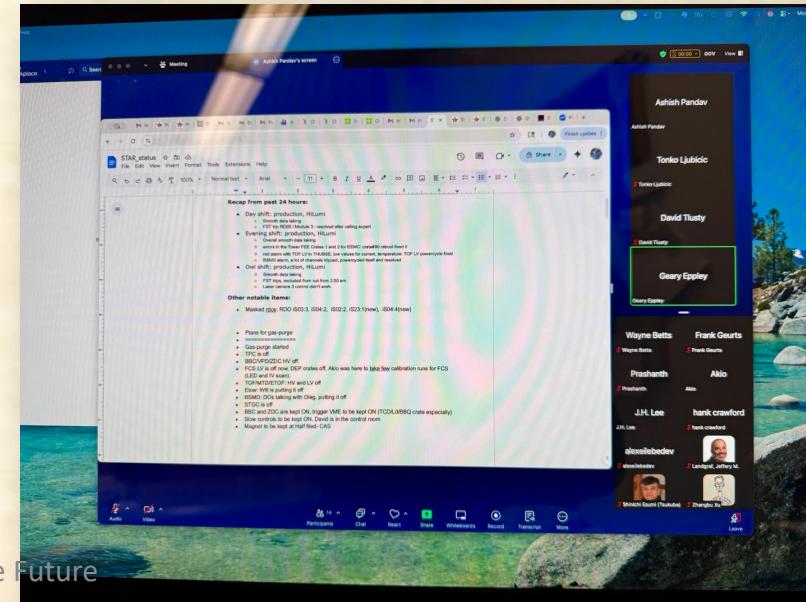


Courtesy of Blair Stringfellow

- ... to Last Collisions

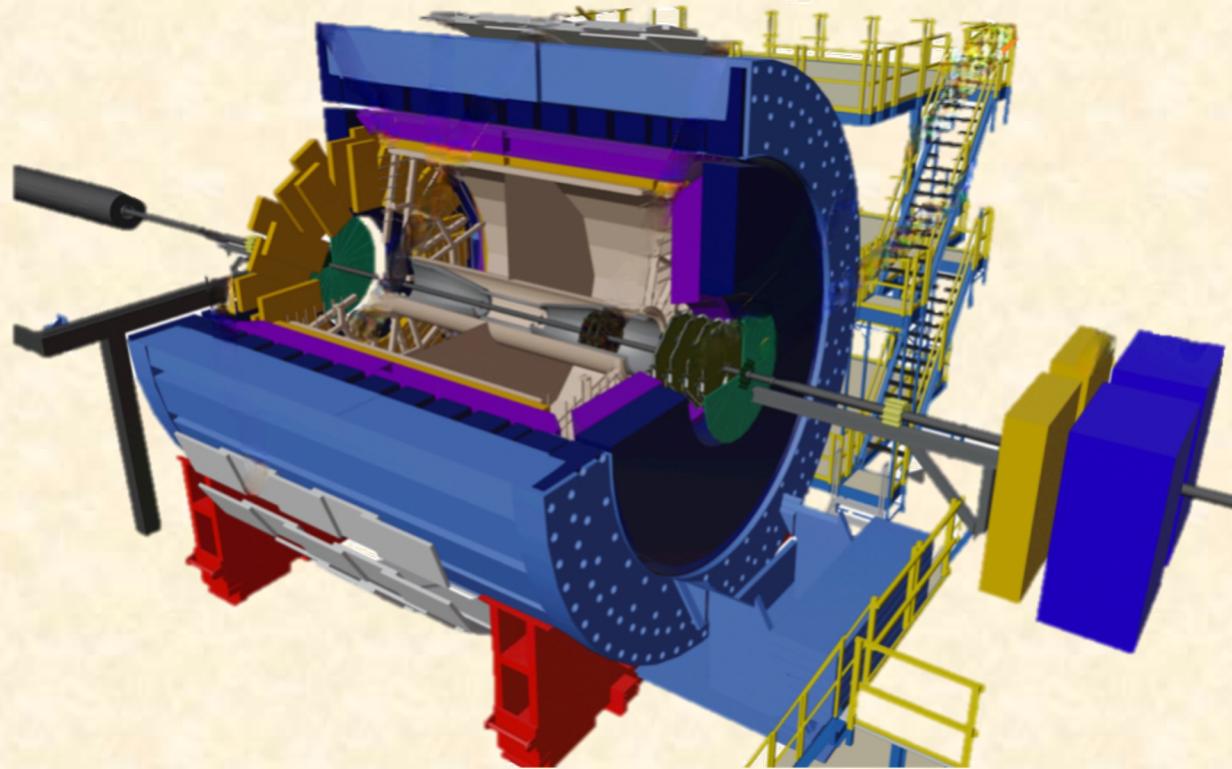


Courtesy of Jamie Dunlop



STAR-25: Looking to the Future

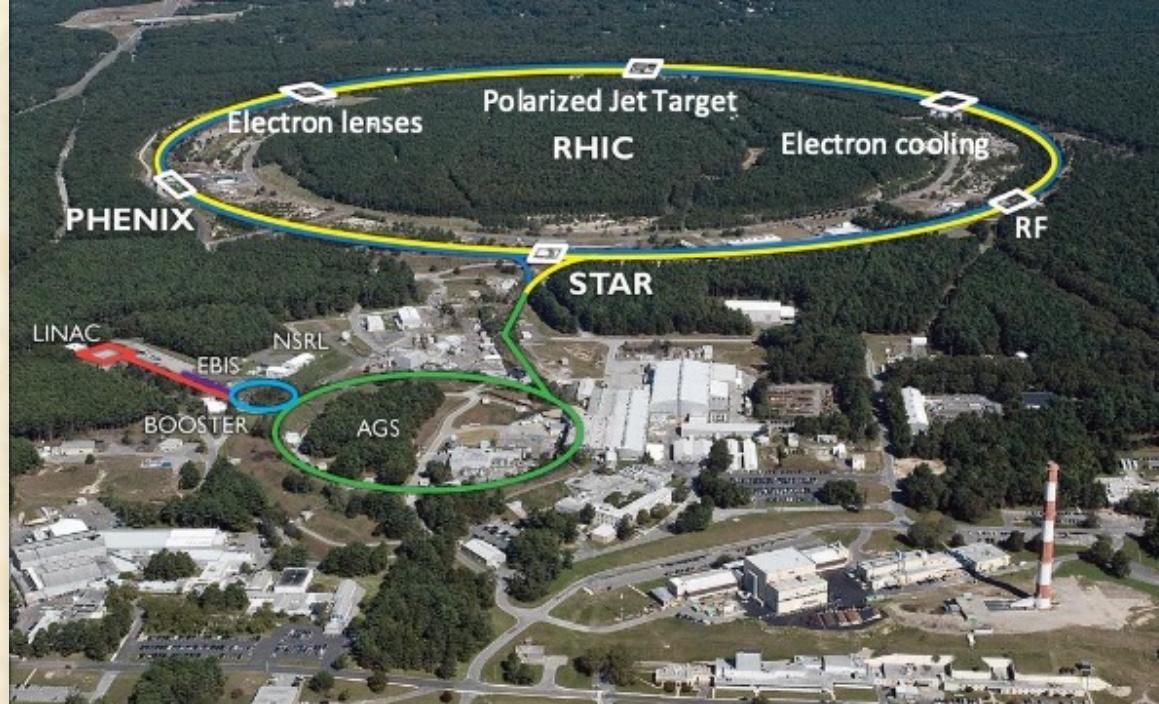
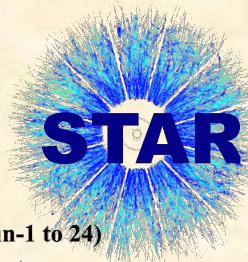
The STAR Detector at 25 years ...



Detector	primary functions	DOE+(in-kind)	year
TPC+Trigger	$ \eta < 1$ Tracking		1999-
Barrel EMC	$ \eta < 1$ jets/ $\gamma/\pi^0/e$		2004-
FTPC	forward tracking	(Germany)	2002-2012
L3	Online Display	(Germany)	2000-2012
SVT/SSD	V0/charm	(France)	2004-2007
PMD	forward photons	(India)	2003-2011
EEMC	$1 < \eta < 2$ jets/ π^0/e	(NSF)	2005-
Roman Pots	diffractive		2009-
TOF	PID	(China)	2009-
FMS/Preshower	$2.5 < \eta < 4.2$	(Russia)	2008-2017
DAQ1000	x10 DAQ rate		2008-
HLT	Online Tracking	(China/Germany)	2012-
FGT	$1 < \eta < 2$ W^\pm		2012-2013
GMT	TPC calibration		2012-
HFT/SSD	open charm	(France/UIC)	2014-2016
MTD	muon ID	(China/India)	2014-
EPD	event plane	(China)	2018-
RHICf	$\eta > 5 \pi^0$	(Japan)	2017
iTPC	$ \eta < 1.5$ Tracking	(China)	2019-
eTOF	$-2 < \eta < -1$ PID	(Germany/China)	2019-
FCS	$2.5 < \eta < 4$ calorimeter	(NSF)	2021-
FTS	$2.5 < \eta < 4$ Tracking	(NCKU/SDU)	2021-

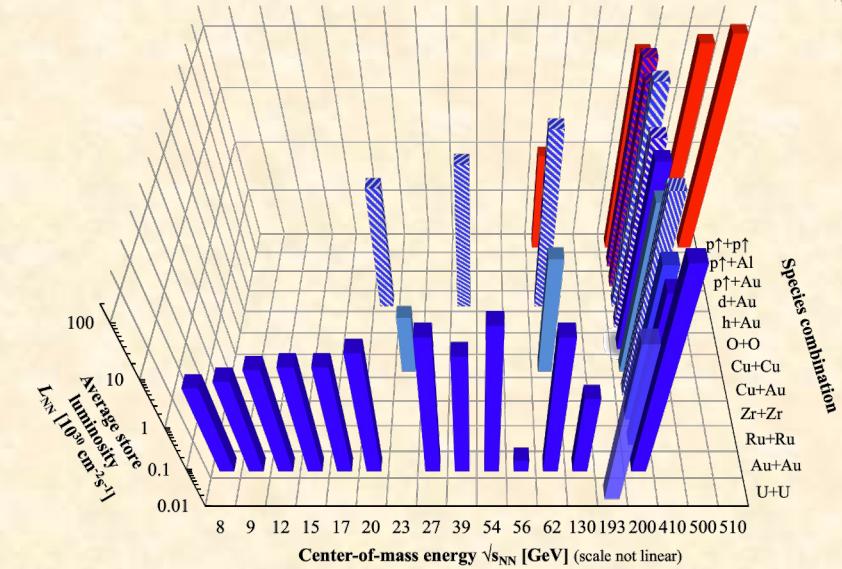
- Extended detection capabilities following 20+ upgrades

25 years of RHIC and STAR



www.agsrhichome.bnl.gov/RHIC/Runs/

RHIC energies, species combinations and luminosities (Run-1 to 24)



- “RHIC: the world’s first purpose-built heavy ion collider”
- Wide range of beam energies and collision systems
 - “The most versatile collider ever built!”

[Bill Zajc, 2025 RHIC-AGS Users’ Meeting]

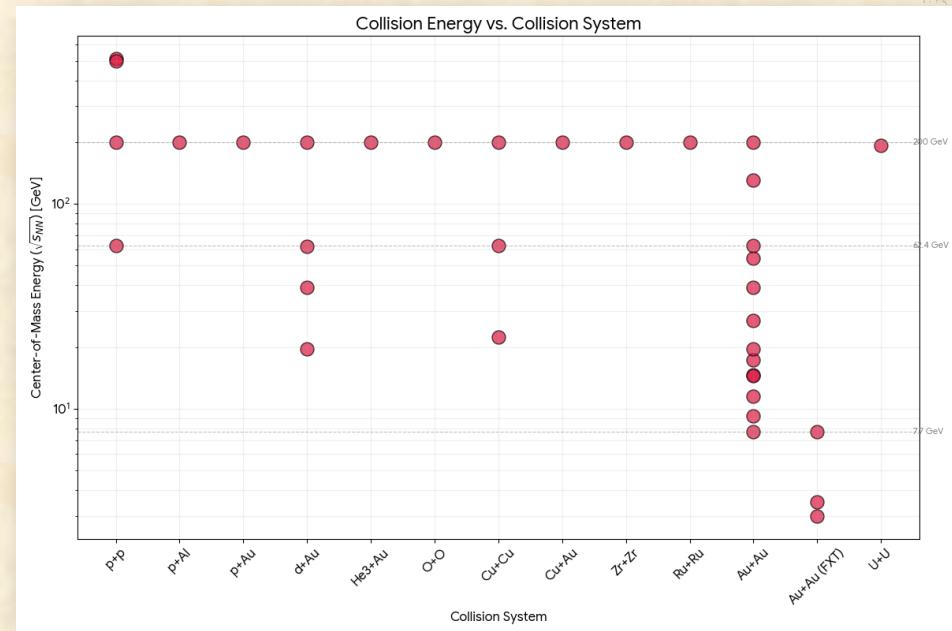
25 years of STAR operations



Courtesy of Gemini

Run	Year	System(s)	\sqrt{s}_{NN} (GeV)	Notes
Run-1	2000	Au+Au	130	~1.6 M events (First data)
Run-2	2001	Au+Au	200	~4 M
		p+p	200	~10 M (polarized)
Run-3	2002	d+Au	200	~15 M
		p+p	200	~15 M
Run-4	2003	Au+Au	200, 62.4	~80 M (200 GeV)
		p+p	200	~40 M
Run-5	2004	Cu+Cu	200, 62.4, 22.4	High stats Cu+Cu scan
		p+p	200	
Run-6	2006	p+p	200, 62.4	High statistics polarized proton
Run-7	2007	Au+Au	200	~80 M (Low mass dilepton focus)
Run-8	2008	d+Au	200	
		p+p	200	Low material run
Run-9	2009	p+p	500, 200	First 500 GeV p+p run (~W physics)
Run-10	2010	Au+Au	200, 62.4, 39, 11.5, 7.7	BES-I Start; ~4-250 M events/energy
		p+p	200	
Run-11	2011	Au+Au	19.6, 27, 200	BES-I continuation; Heavy Flavor focus
		p+p	500	
Run-12	2012	U+U	193	
Run-13	2013	Cu+Au	200	First U+U and Cu+Au collisions
		p+p	200, 510	
Run-14	2014	Au+Au	200, 14.5	HFT installed; BES-I completion (14.5)
		He ³ +Au	200	

Run	Year	System(s)	\sqrt{s}_{NN} (GeV)	Notes
Run-15	2015	p+p	200	
		p+Au	200	Transverse spin; Cold QCD
Run-16	2016	p+Al	200	
		Au+Au	200	Heavy Flavor program; Small system scan
Run-17	2017	d+Au	200, 62, 39, 19.6	
		p+p	510	Transverse spin; Magnetic field study
Run-18	2018	Au+Au	54.4	
		Ru+Ru, Zr+Zr	200	Isobar Run (>3 B/species); iTPC upgrade
Run-19	2019	Au+Au	19.6, 14.6	BES-II Start; Fixed Target (FXT) initiation
		Au+Au (FXT)	3.0 - 7.7 (scan)	
Run-20	2020	Au+Au	11.5, 9.2	BES-II Collider + FXT high stats (~100 M+)
		Au+Au (FXT)	3.5, 3.9, 4.5, 5.2, 6.2, 7.7	
Run-21	2021	Au+Au	7.7	BES-II Finish; Test runs for O+O
		O+O / d+Au	200	
Run-22	2022	p+p	510	Forward Upgrade
Run-23	2023	Au+Au	200	High stats Au+Au; Forward Physics
		p+p	200	
Run-24	2024	Au+Au	17.3	
		p+p	200	Cold QCD & Forward Physics
Run-25	2025	Au+Au	200	High statistics final Au+Au run
		Au+Au (FXT)	4.5	Requested: High statistics final FXT run



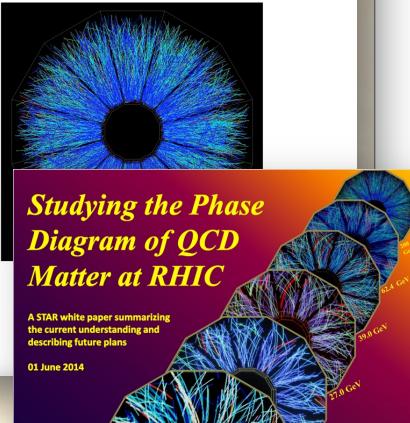
- 25 RHIC Runs
- 13 collision systems
 - Incl. Fixed Target
- 15+ energy and spin configs

25 years of Beam Use Requests



RHIC Multi-Year Beam Use Request
For Run 9 – Run 13

The STAR Collaboration
April 21, 2008



The RHIC Cold QCD Plan for 2024 to 2028
Completing the RHIC Science Mission

Authors for the RHIC SPIN Collaboration*
Elke-Caroline Aschenauer¹, Alexander Bazilevsky¹, Xiaoxian Chu¹, Oleg Ener¹, René Feser¹, Carl Gagliardi¹, Ting Lin², Jie D. Nam³, Ralf Seidl¹, Caroline Riedl¹, and Scott Wissick¹
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⁷University of Illinois Urbana-Champaign, Urbana 61801
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RHIC Beam Use Request
For Runs 15 and 16

The STAR Collaboration

RHIC Beam Use Request
For Runs 16 and 17

The STAR Collaboration

RHIC Beam Use Request
For Runs 17 and 18

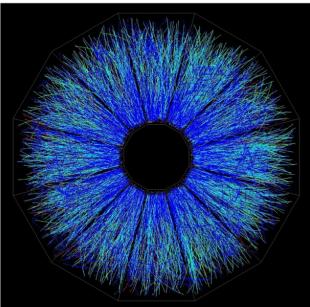
The STAR Collaboration

RHIC Beam Use Request
For Runs 18 and 19

The STAR Collaboration

The STAR Beam Use Request for Runs 19 and 20

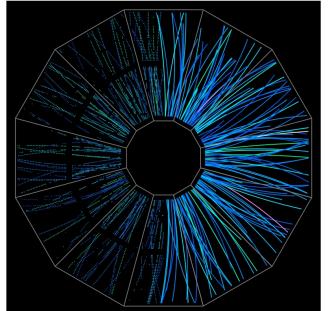
The STAR Collaboration



May 1, 2018

The STAR Beam Use Request for Run-20 and Run-21

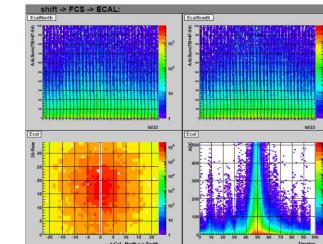
The STAR Collaboration



May 15, 2019

The STAR Beam Use Request for Run-22 and data taking in 2023-25

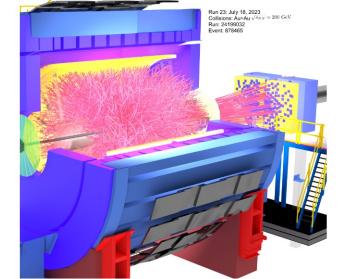
The STAR Collaboration



STAR BUR Runs 24 - 25

STAR Collaboration

2023



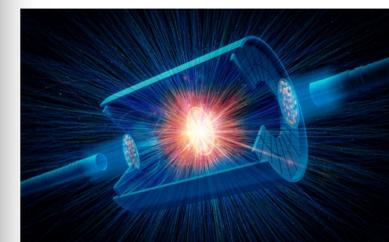
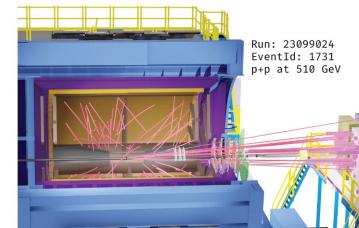
STAR BUR Run 25

STAR Collaboration

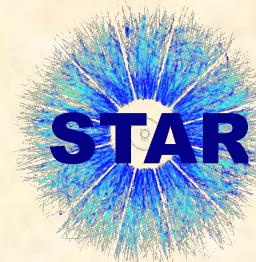
November 1, 2024

The STAR Beam Use Request for Run-23-25

The STAR Collaboration

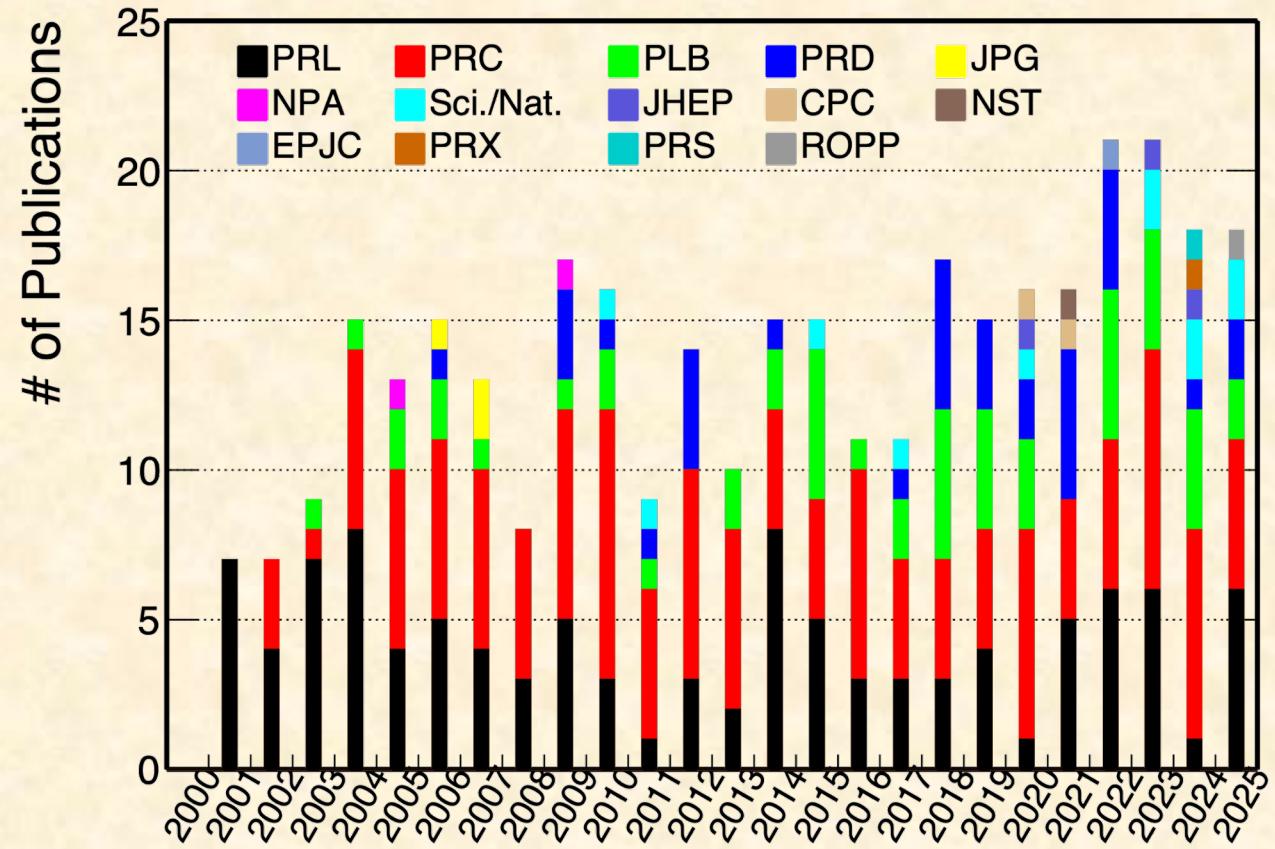


25 years of Physics Publications

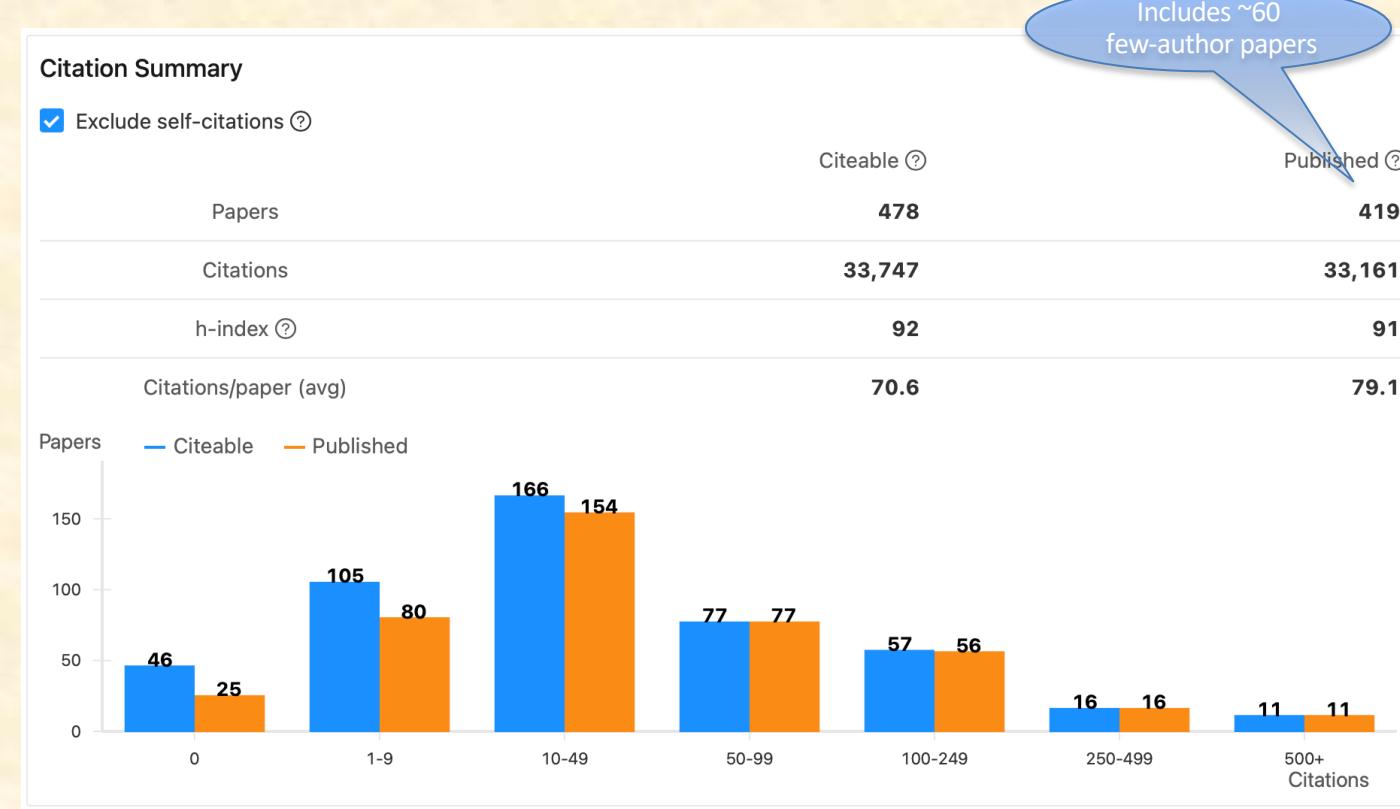


Total: 347 published physics papers

- PRL: 107, PRC: 130, PLB: 50, PRD: 34, Sci/Nat: 11, Others: 15
- STAR Theses:
 - 347 PhD theses
 - 34 MS theses
 - 10 Diploma theses

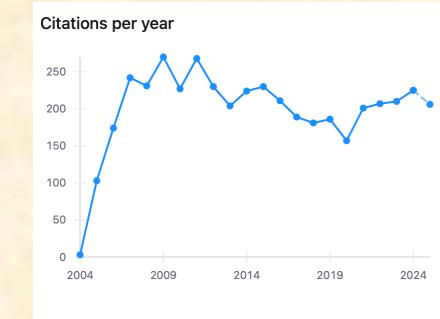


STAR Impact

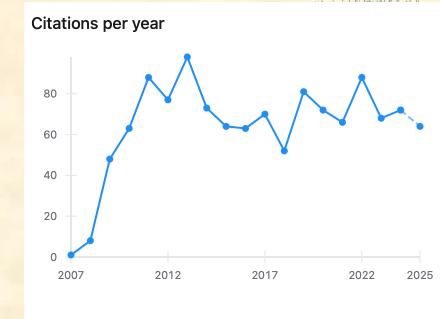


src: INSPIRE

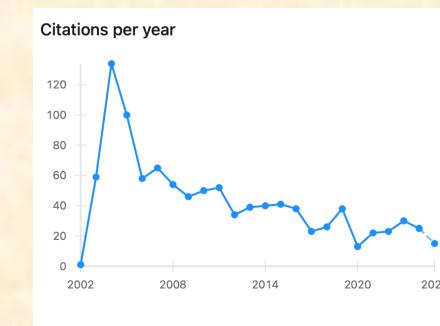
- 1000+ citations :: 4 papers
 - STAR white paper - 4379 citations
- 900 – 1000 citations :: 4 papers
 - Including NIM-A STAR Detector Overview



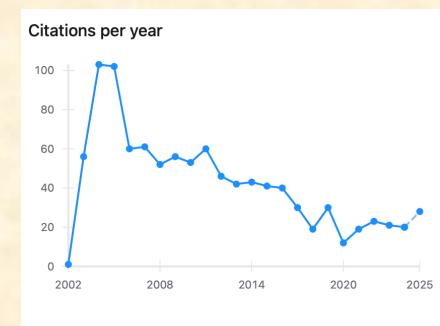
White Paper - NPA 2005



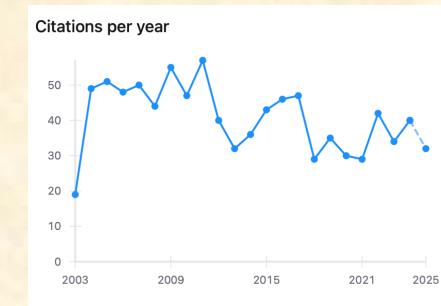
BES 1 Spectra - PRC 2009



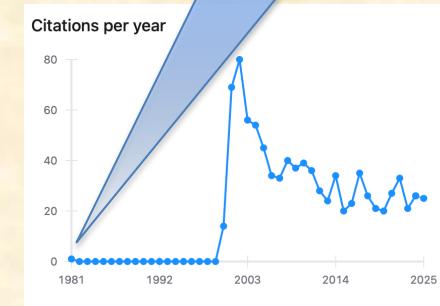
R_{dA} 200 GeV - PRL 2003



R_{AA} 200 GeV - PRL 2003



STAR Detector – NIM-A 2002



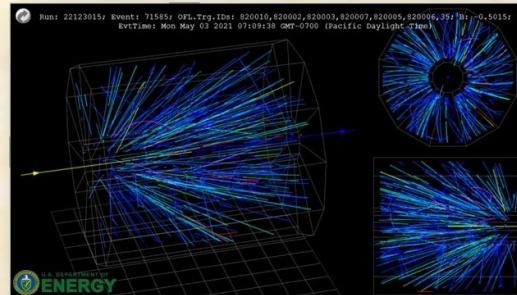
V₂ 130 GeV - PRL 2001

src: INSPIRE

Recent DOE Office of Science NP Highlights



December 6, 2022

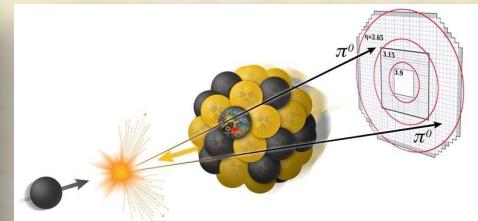


March 22, 2023



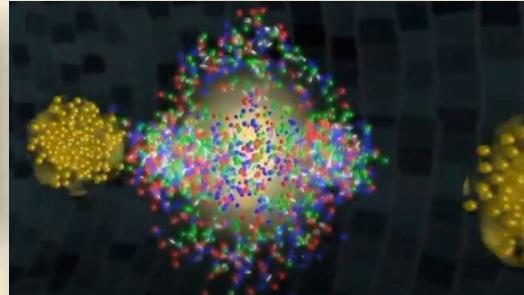
Scientists Narrow the Anchor Point
in a Quantum Chromodynamics
Critical Point Search

March 24, 2023

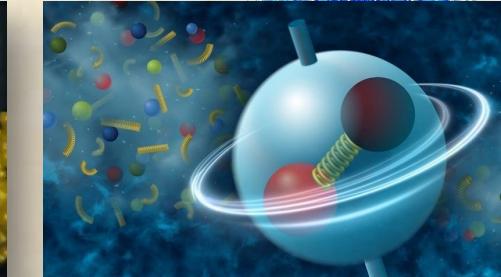


Signs of Gluon Saturation Emerge
from Particle Collisions

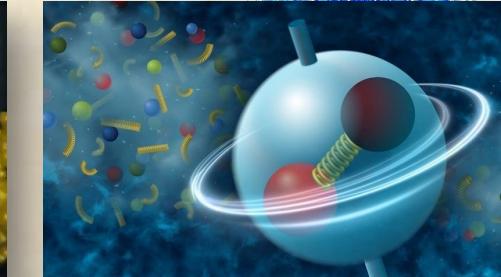
April 7, 2023



New Findings on the Flow of
Particles in Heavy Ion Collisions

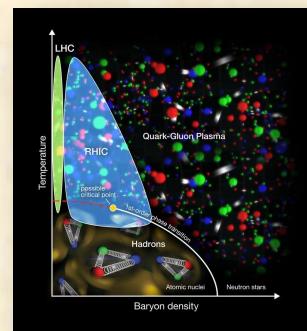


May 5, 2023



Surprising Preference in
Particle Spin Alignment

June 5, 2023



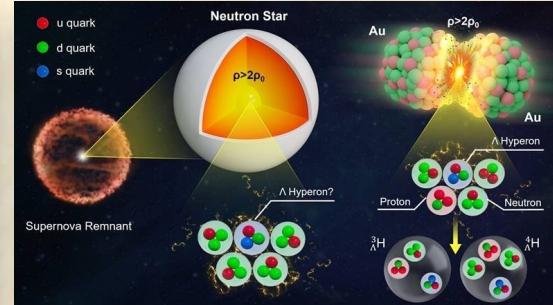
A Low-Energy 'Off Switch'
for Quark-Gluon Plasma

June 15, 2023



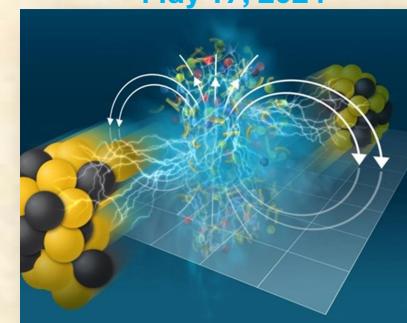
STAR Physicists Track Sequential
'Melting' of Upsilonons

August 21, 2023



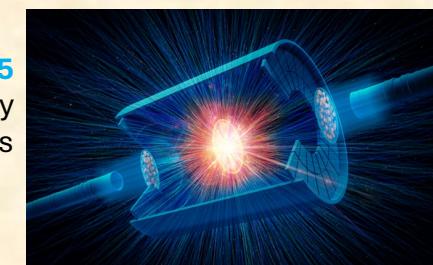
New Insights into How Strange Matter
Interacts with Ordinary Matter

May 17, 2024

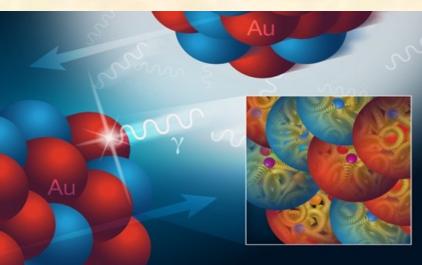


STAR Sees a Magnetic Imprint on
Deconfined Nuclear Matter

April 7, 2025



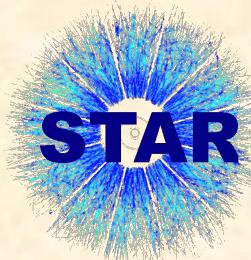
Imaging Nuclear Shapes by
Smashing Them to Smithereens



April 14, 2025

Gluons' Density Isn't the Same
in Bound vs Unbound Protons
and Neutrons

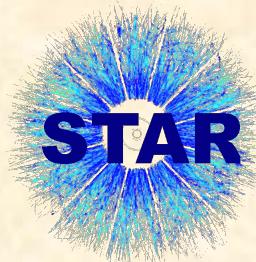
A Pipeline of Future Publications



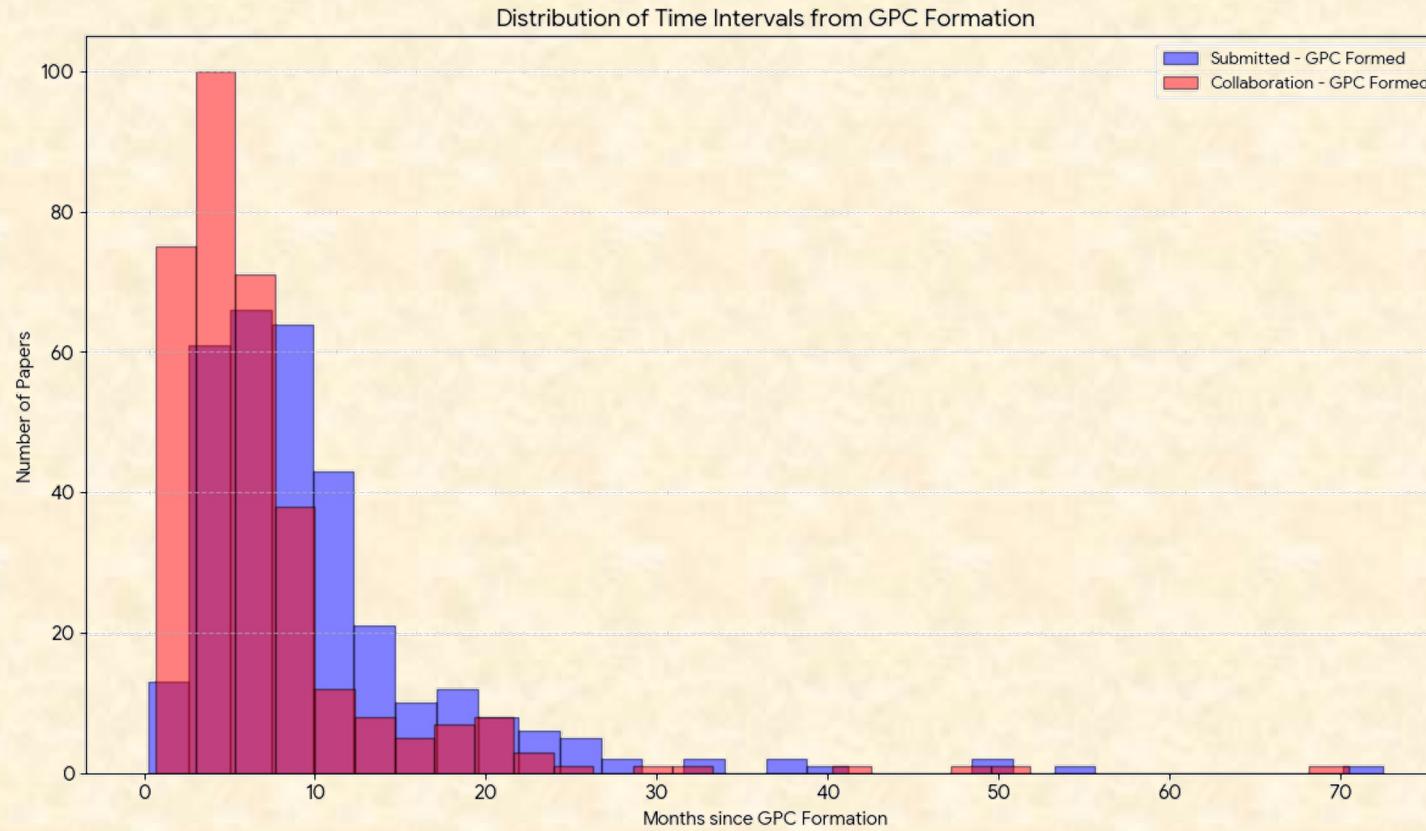
- 51 Active GPCs
 - ColdQCD - 4, CF - 9, FCV - 12, HP - 13, LFSUPC - 13
 - Papers submitted, in journal review - 16 [2, 3, 5, 2, 4]
 - Papers in collaboration review - 4 [0, 0, 1, 2, 1]
 - Papers before release to collaboration - 31 [1, 6, 6, 10, 8]
 - 33 new GPCs formed in 2025 (CQ - 3, CF - 7, FCV - 7, HP - 7, LFSUPC - 9)
- 13 PWGC previews since Summer Collaboration Meeting
 - ColdQCD - 1, CF - 3, FCV - 2, HP - 0, LFSUPC - 7

src: <https://www.star.bnl.gov/protected/common/GPCs/gpc-committees.xml>

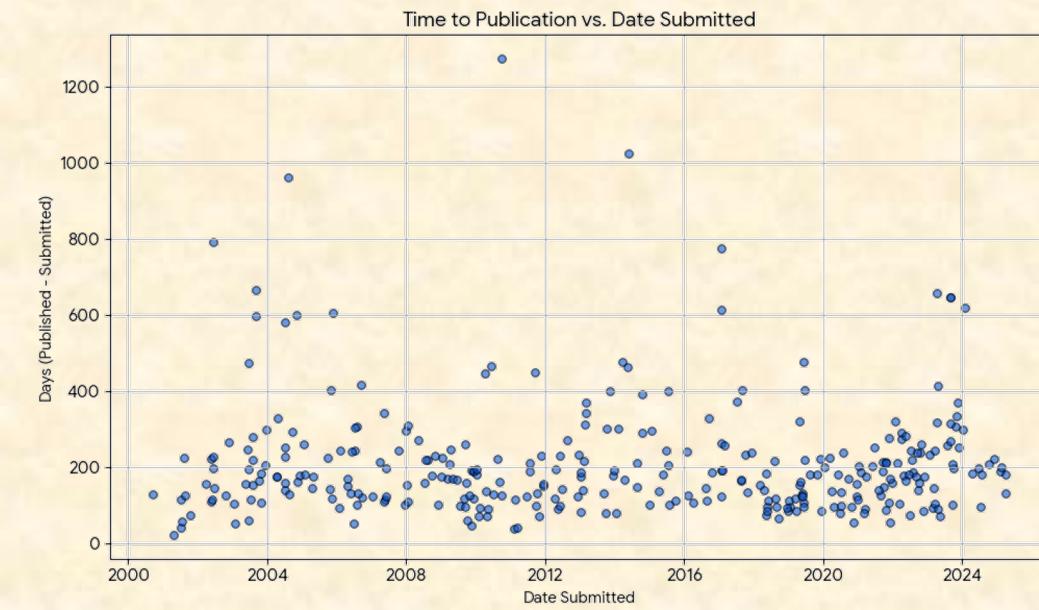
Internal Timelines: from GPC to Journal



- From GPC formation to Collaboration review: mode \sim 3-4 months
- From GPC formation to Journal Submission: mode \sim 7-8 months
 - collaboration review = 2 weeks
 - final version review (1wk) + RHIC announcement (5 days) = 2wks



Time-to-Publication (days) vs. submission year



Journal Peer review:
not much change over the years ...

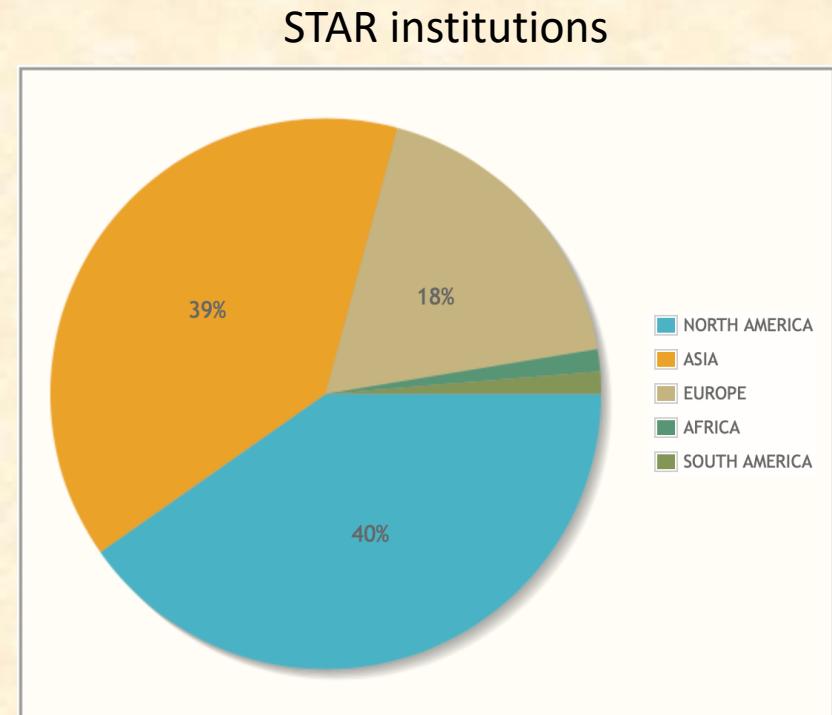
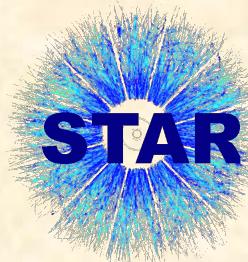
Where are we now?

- STAR is a very active collaboration
 - 2nd largest heavy-ion collaboration
 - 741 members, 77 institutions, 14 countries
 - 399 authors, 401 juniors, 11 emeritus

➤ STAR is a young collaboration!

- *many* collaborators were **involved in shifts**
 - Runs 24 and 25 were long runs
- *many* collaborators are **involved in GPCs**
 - 51 active GPCs with each ~4-5 members
- in between, *many* are providing **essential service work**: calibration/production/embedding, QA, PWGs, paper reviews

Internally proposed abstracts:
QM23: 86 proposed
QM25: 84 proposed



Post-Operations Era

- Monday Dec.8: the last year of operations concluded
- Next year : transition to post-ops
- Next years : continued strong science output

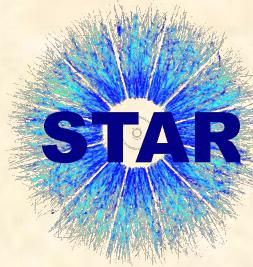
STAR Council Chair, together with SP Office form Taskforce/Committee to:

- advise on post-ops authorship rules
- adjust publication policies
- initiate service-tasks standing committee

➤ Ask your Council Rep

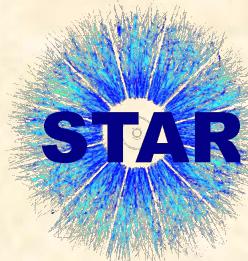


Software & Computing



- Central role in operations and reconstruction
 - critical to STAR's future
- Increasing complexity
 - more subdetectors ⇒ increasingly larger code base
 - more data ⇒ more constraints from available resources
 - See, e.g., [STAR Note 753](#)
- Many thanks to a very strong local team at BNL
 - excellent support from NERSC team
 - many opportunities for graduate students and postdocs to contribute

Where's the Data?!



- Recent pp (Run-22 + 24) and Au+Au (Run-23 +25)
 - these are large datasets
 - Run 22 pp500 : 11B events
 - Run 24 pp200: 14.7B events
 - Run 23-24-14 AuAu200: $7.5B + 1.9B + 9.2B = 18.6B$ (HiLumi'25 : 4.3B)
 - include many subdetectors, incl. STAR's full suite of FWD detection capabilities
- Production will likely take extended periods of time
- Careful QA is even more relevant now
 - library & calibration readiness will require utmost attention
 - prompt QA feedback from PWGs critical for timely delivery
- Looking at opportunities to explore new, creative options to expedite productions

Bountiful Physics

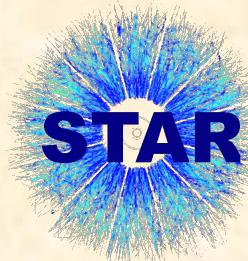
Program ahead

1. What is the nature of the 3-dimensional **initial state** at RHIC energies?
2. What is the precise temperature dependence of the shear (η/s) and bulk (ζ/s) **viscosities**?
3. What can we learn about **[de-confinement]** from charmonium measurements?
4. What is the **temperature** of the medium?
5. What are the electrical, magnetic, and chiral **properties of the medium**?
6. What are the underlying mechanisms of **jet quenching** at RHIC energies?
7. What is the precise **nature of the transition** near $\mu_B = 0$?
8. What can we learn about the **strong interaction**?

Observable	Question	PWG	MB/H \mathcal{L}	Coverage	Trigger
$v_2(\eta)$ Twist	1) Initial State	FCV	Min bias	iTPC, TOF, EPD, FTS	MB
$r_n(\eta_a, \eta_b)$	1) Initial State	FCV	Min Bias	iTPC, TOF, EPD, FTS	MB
$J/\psi v_1$	1) Initial State	HP	Luminosity	iTPC, TOF, EPD	MB+BHT
Photon WF	1) Initial State	LFSUPC	Min Bias	iTPC, TOF	MB
$v_2(\eta)$	2) Viscosity	FCV	Min bias	iTPC, TOF, EPD, FTS	MB
$J/\psi v_2$	3) Deconfinement	HP	Luminosity	iTPC, TOF, EPD	MB+BHT
Υ Suppression	4) Temperature	HP	Luminosity	iTPC, TOF	BHT+Dimuon
$\psi(2s)$ suppress.	4) Temperature	HP	Min Bias	iTPC, TOF	MB
Di-elec IMR	4) Temperature	LFSUPC	Min Bias	iTPC, TOF	MB
$P_H(\eta)$	5) Properties	FCV	Min Bias	iTPC, TOF, FTS, EPD	MB
P_H of J/ψ	5) Properties	FCV	Luminosity	iTPC, TOF, EPD	MB+BHT
$\rho^0 a_1$ mixing	5) Properties	LFSUPC	Min Bias	iTPC, TOF	MB
Di-elec LMR	5) Properties	LFSUPC	Min Bias	iTPC, TOF	MB
CME	5) Properties	FCV	Min Bias	iTPC, TOF, EPD	MB
γ_{Dir} + jet I_{AA}	6) Jet quenching	HP	Luminosity	BEMC, EEMC FCS	BHT
γ_{Dir} + jet acopl.	6) Jet quenching	HP	Luminosity	BEMC, EEMC, FCS	BHT
Jet substruct.	6) Jet quenching	HP	Luminosity	BEMC, EEMC, FCS	BHT
Net-p C_6	7) Phase Transition	CF	Min Bias	iTPC, TOF	MB
Baryon CF	8) Strong Interact.	CF	Min Bias	iTPC, TOF	MB
UPC $\rho^0, \phi, J/\psi$	UPC – CNM	LFSUPC	Luminosity	iTPC, TOF, BEMC, EEMC	ZDCEW, UPC
v_2 in γ +Au (UPC)	UPC – CNM	FCV	Min Bias	iTPC, TOF, FTS	UPC
UPC di-jets	UPC – CNM	HP	Luminosity	iTPC, TOF, BEMC	UPC+BHT
UPC CP spectra	UPC – CNM	LFSUPC	Min Bias	iTPC, TOF	ZDCE(1n)+ZDCW

BUR 2025, STAR Note 850

Data & Analysis Preservation

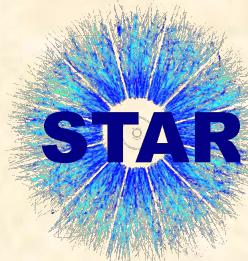


- work closely with BNL for common strategies
 - RHIC DAPP initiative successfully completed recent external review (July 1, '25)
- proactively engage with partners at BNL (SCDF, ITD, NPPS) and outside BNL (HEPdata)
 - improve accessibility to mailing lists hosted on SYMPA (ITD)
 - upgrade Drupal and transition to centralized services (SCDF)
 - bookkeeping tools for HEPdb submissions (HEPdata)
- STAR internal
 - software/environment upgrades (ROOT, Linux OS, Containers)
 - RAG/LLM tools to improve access to a wide range of internal knowledge
 - improve research-data-management and user management tools

➤ Need a strongly engaged collaboration

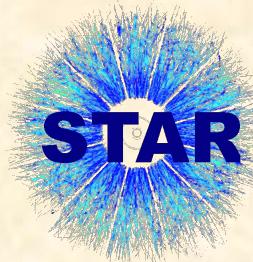
- opportunities for students and postdocs to gain experience and innovate
- opportunities for institutions to take “ownership”

What else is next, in the near future?



- ✓ ORCID required for all STAR authors
 - DOE/BNL require it
 - Journals ask for it
- ✓ Updated STAR Phonebook App
 - improvements for updating your own information
- Unified access to mailing-list archives
 - including GPC mailing list
- InCommon roll-out
 - better and more uniform access to collaborative resources
- Drupal update
 - (note to self: also update its “future” section!)

Coming up at the next Collaboration Meeting



STAR Early Career Awards



To recognize and honor outstanding early career members for their work and dedication to service tasks.



« Don't forget to nominate! »

APS DNP Community Townhall Meeting



- Online only
- Monday January 12, 1 – 5pm (EST)
- Agenda & Registration: <https://indico.phys.utk.edu/event/290>

➤ Important to see a good representation of the RHIC community

Timetable			
Mon 12/01			
	 Print  PDF  Full screen  Detailed view  Filter	 Session legend	
13:00	Welcome and Introduction	Nadia Fomin	13:00 - 13:10
	Post-NSAC Landscape	TBD	13:10 - 13:25
	Nuclear Structure, Reactions and Astrophysics	Ani Arahamian	13:25 - 13:45
	Hot and Cold QCD	Richard Milner	13:45 - 14:05
14:00	TBD		14:05 - 14:20
	Fundamental Symmetries, Neutrons and Neutrinos	Brent VanDevender	14:20 - 14:40
	Nuclear Theory	Filomena Nunes	14:40 - 15:00
15:00	Workforce Development and Outreach	Shelly Lasher	15:00 - 15:10
	Break		15:10 - 15:20
	LRP Budget	Sherry Yennello	15:20 - 15:40
	DOE Report		15:40 - 16:10
16:00	NSF report		16:10 - 16:40
	Moderated Q&A	Jim Napolitano	16:40 - 17:00
17:00			

Summary

- **STAR is a highly productive collaboration**
 - Thanks to the engagement of many institutes and individuals
- **25 years of carefully acquired datasets**
 - Runs 22 – 25 will be an excellent legacy with physics potential beyond our BURs
 - 8-10 years of exciting physics ahead of us!
- **Expect some changes in our collaborative tools while we prepare for the future**
 - Going head-in-hand with STAR's data preservation efforts
- **STAR also serves as an incubator of leadership talent!**
 - Many opportunities for postdocs and graduate students

➤ **Communication is essential.**

- Please let us know of any concerns, new ideas, and ambitions!!



STAR's Future is Bright!

