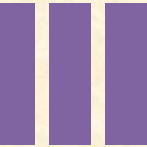




Looking to the Future

Frank Geurts
Rice University



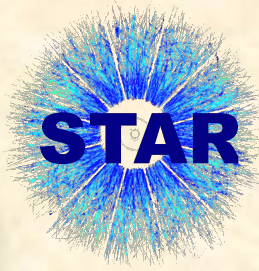
Looking back

- From First Collisions

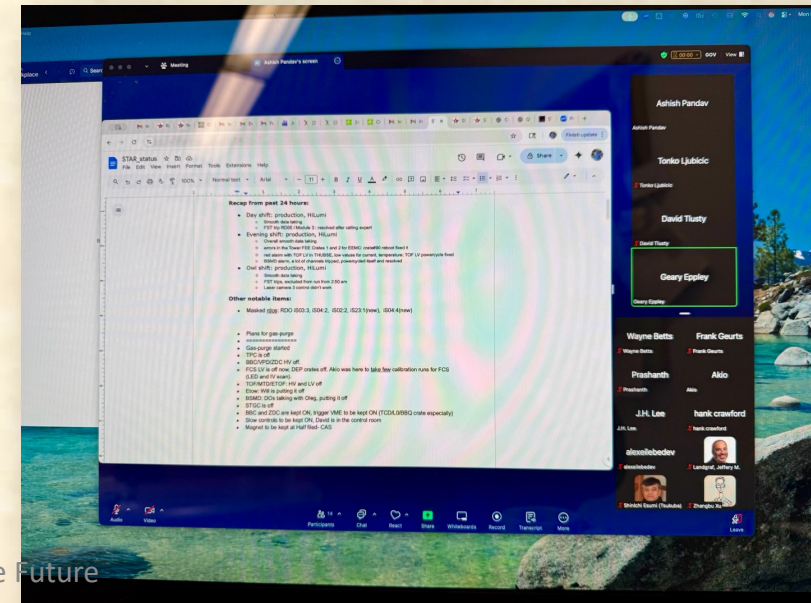
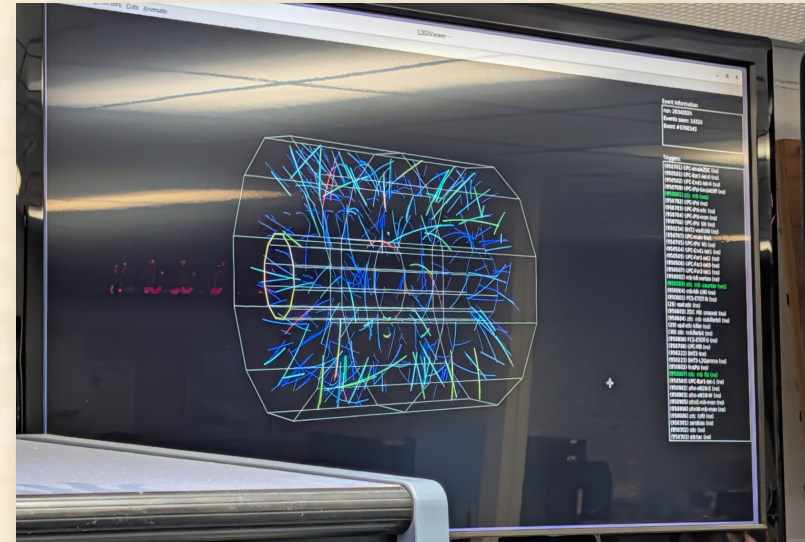


Courtesy of Blair Stringfellow

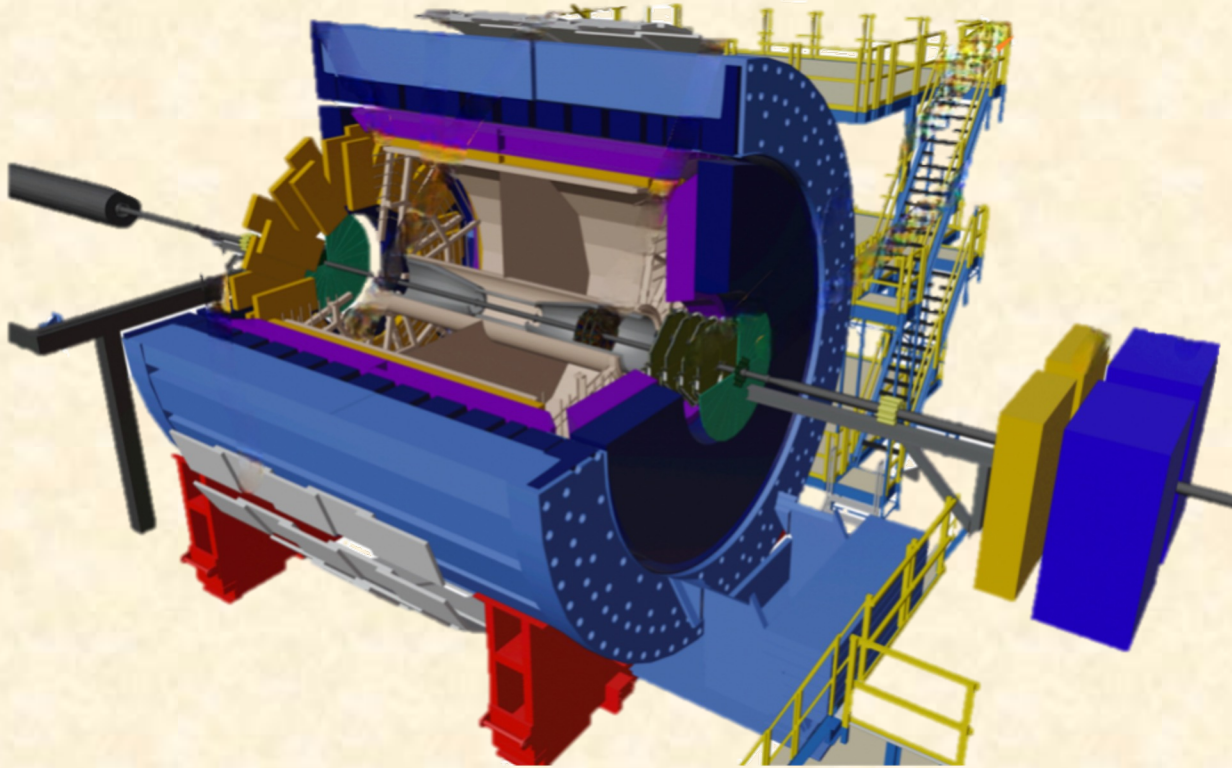
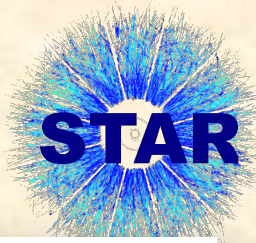
- ... to Last Collisions



Courtesy of Jamie Dunlop



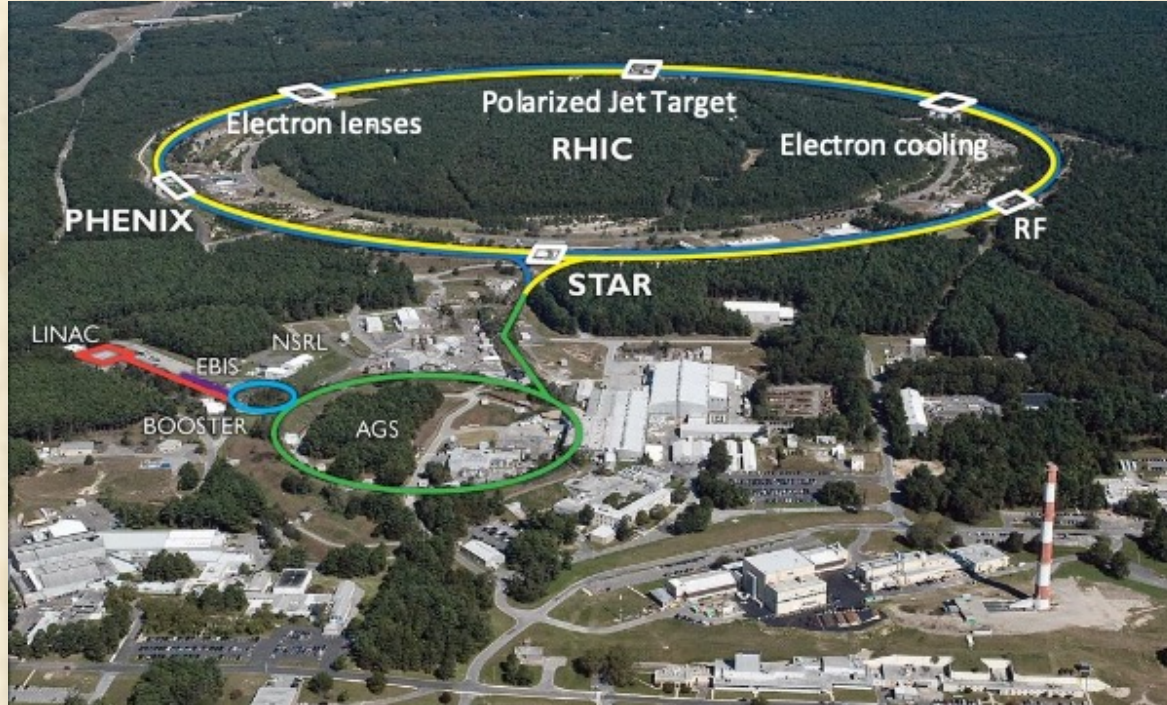
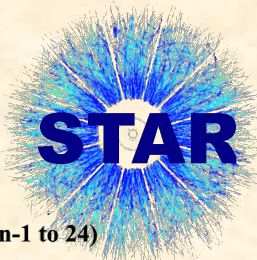
The STAR Detector at 25 years ...



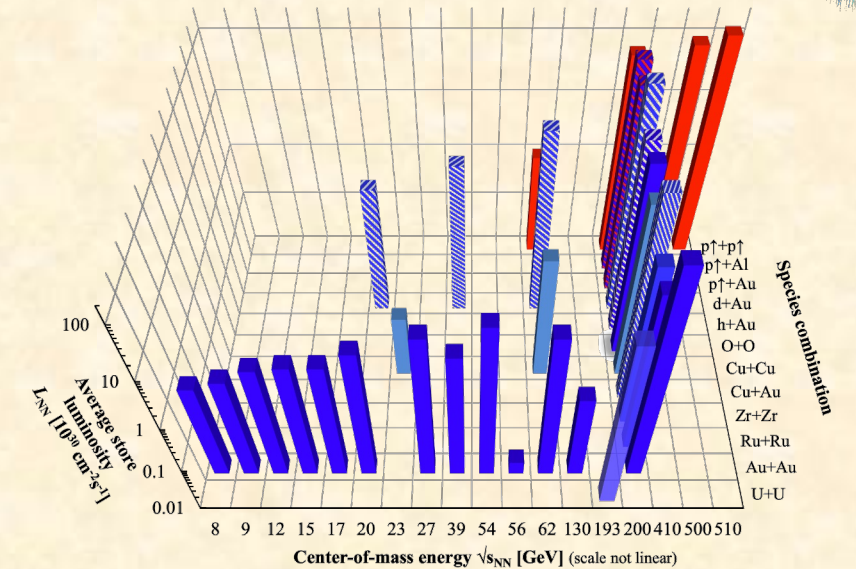
Detector	primary functions	DOE+(in-kind)	year
TPC+Trigger	$ \eta < 1$ Tracking		1999-
Barrel EMC	$ \eta < 1$ jets/ $\gamma/\pi^0/e$		2004-
FTPC	forward tracking	(Germany)	2002-2012
L3	Online Display	(Germany)	2000-2012
SVT/SSD	V0/charm	(France)	2004-2007
PMD	forward photons	(India)	2003-2011
EEMC	$1 < \eta < 2$ 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	$\eta > 5$ π^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

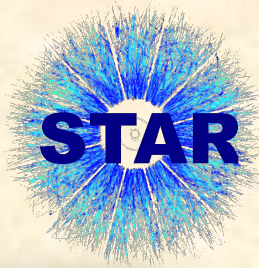


www.agsrhichome.bnl.gov/RHIC/Runs/
RHIC energies, species combinations and luminosities (Run-1 to 24)



- “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]

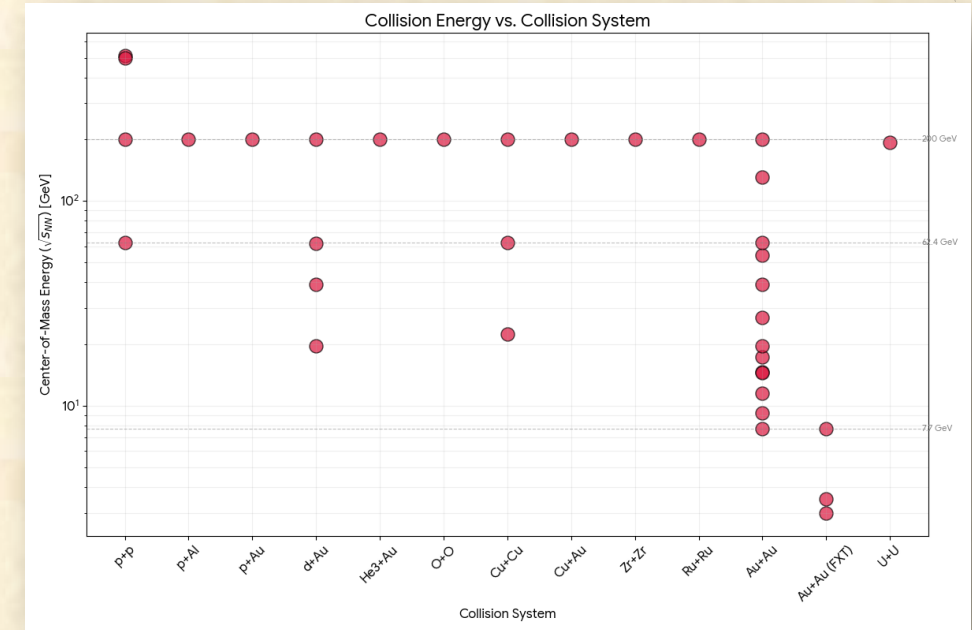
25 years of STAR operations



Courtesy of Gemini

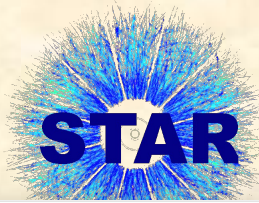
Run	Year	System(s)	$\sqrt{s_{NN}}$ (GeV)	Notes
Run-1	2000	Au+Au	130	~1.6 M events (First data)
Run-2	2001	Au+Au	200	~4 M
		p+p	200	~10 M (polarized)
Run-3	2002	d+Au	200	~15 M
		p+p	200	~15 M
Run-4	2003	Au+Au	200, 62.4	~80 M (200 GeV)
		p+p	200	~40 M
Run-5	2004	Cu+Cu	200, 62.4, 22.4	High stats Cu+Cu scan
		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	Low material run
		p+p	200	
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	First U+U and Cu+Au collisions
		Cu+Au	200	
Run-13	2013	p+p	200, 510	High luminosity polarized p+p (~W/Z)
		p+p	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	Transverse spin; Cold QCD
		p+Al	200	
Run-16	2016	Au+Au	200	Heavy Flavor program; Small system scan
		d+Au	200, 62, 39, 19.6	
Run-17	2017	p+p	510	Transverse spin; Magnetic field study
		Au+Au	54.4	
Run-18	2018	Ru+Ru, Zr+Zr	200	Isobar Run (>3 B/species); ITPC upgrade
		Au+Au	27	
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
Run-22	2022	O+O / d+Au	200	
Run-23	2023	p+p	510	Forward Upgrade
		Au+Au	200	
Run-24	2024	p+p	200	High stats Au+Au; Forward Physics
		Au+Au	17.3	
Run-25	2025	p+p	200	Cold QCD & Forward Physics
		p+Au	200	
		Au+Au	200	High statistics final Au+Au run
		Au+Au (FXT)	4.5	



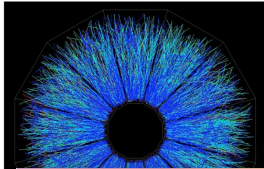
- 25 RHIC Runs
- 13 collision systems
 - Incl. Fixed Target
- 15+ energy and spin configs

25 years of Beam Use Requests



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

The STAR Collaboration
April 21, 2008



Studying the Phase Diagram of QCD Matter at RHIC

A STAR white paper summarizing
the current understanding and
describing future plans
01 June 2014



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

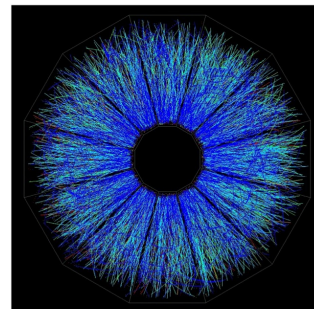
The STAR Collaboration

RHIC Beam Use Request For Runs 18 and 19

The STAR Collaboration

The STAR Beam Use Request for Runs 19 and 20

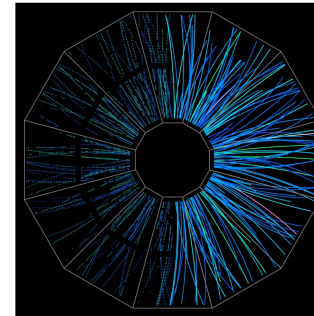
The STAR Collaboration



May 1, 2018

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

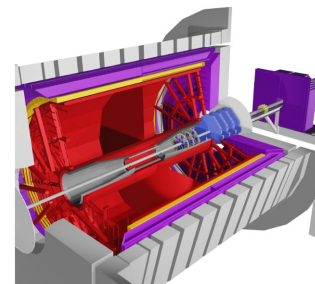
The STAR Collaboration



May 15, 2019

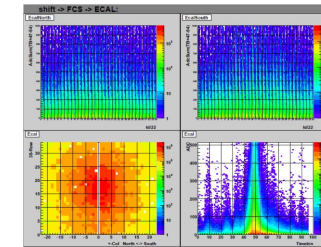
The STAR Beam Use Request for Run-21, Run-22 and data taking in 2023-25

The STAR Collaboration



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

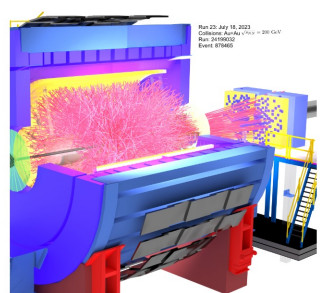
The STAR Collaboration



FCS EMCAL plots from online monitoring during Run-21.
Bottom left: distribution of hits across all the EMCAL modules.
Bottom right: energy deposition as a function of time bin in the electronics readout.
Top: Energy deposition vs module ID.

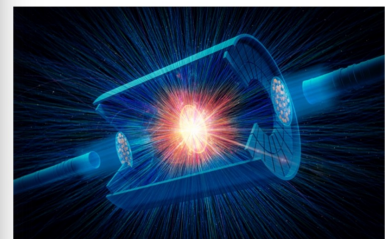
STAR BUR Runs 24 - 25

STAR Collaboration
2023



STAR BUR Run 25

STAR Collaboration
November 1, 2024



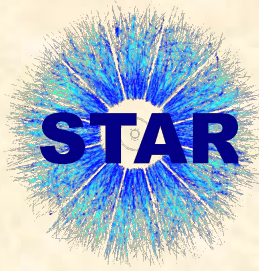
The RHIC Cold QCD Plan for 2024 to 2028 Completing the RHIC Science Mission

Authors for the RHIC SPIN Collaboration*

Elise-Caroline Aschmann¹, Alexander Bazilevsky², Xiaomun Chen³, Oleg Ewer⁴, Renee Farnum⁵, Carl Gagliardi⁶, Ting Lin⁷, Jue D. Nam⁸, Ralf Seidl⁹, Caroline Rodif¹⁰, and Scott Winitz¹¹
¹Brookhaven National Laboratory, Upton, New York 11973
²University of Kentucky, Lexington, Kentucky 40506-0033
³Texas A&M University, College Station, Texas 77843
⁴Shandong University, Qingdao, Shandong 266277
⁵Temple University, Philadelphia, Pennsylvania, 19122
⁶RICE University, Houston, Texas 77005
⁷RICE University, Houston, Texas 77005
⁸University of Illinois Urbana-Champaign, Urbana 61801
⁹Indiana University, Bloomington, Indiana 47408

*The RHIC Spin Collaboration consists of the spin working groups of the RHIC collaboration, many theorists and members of the BNL accelerator department.

25 years of Physics Publications

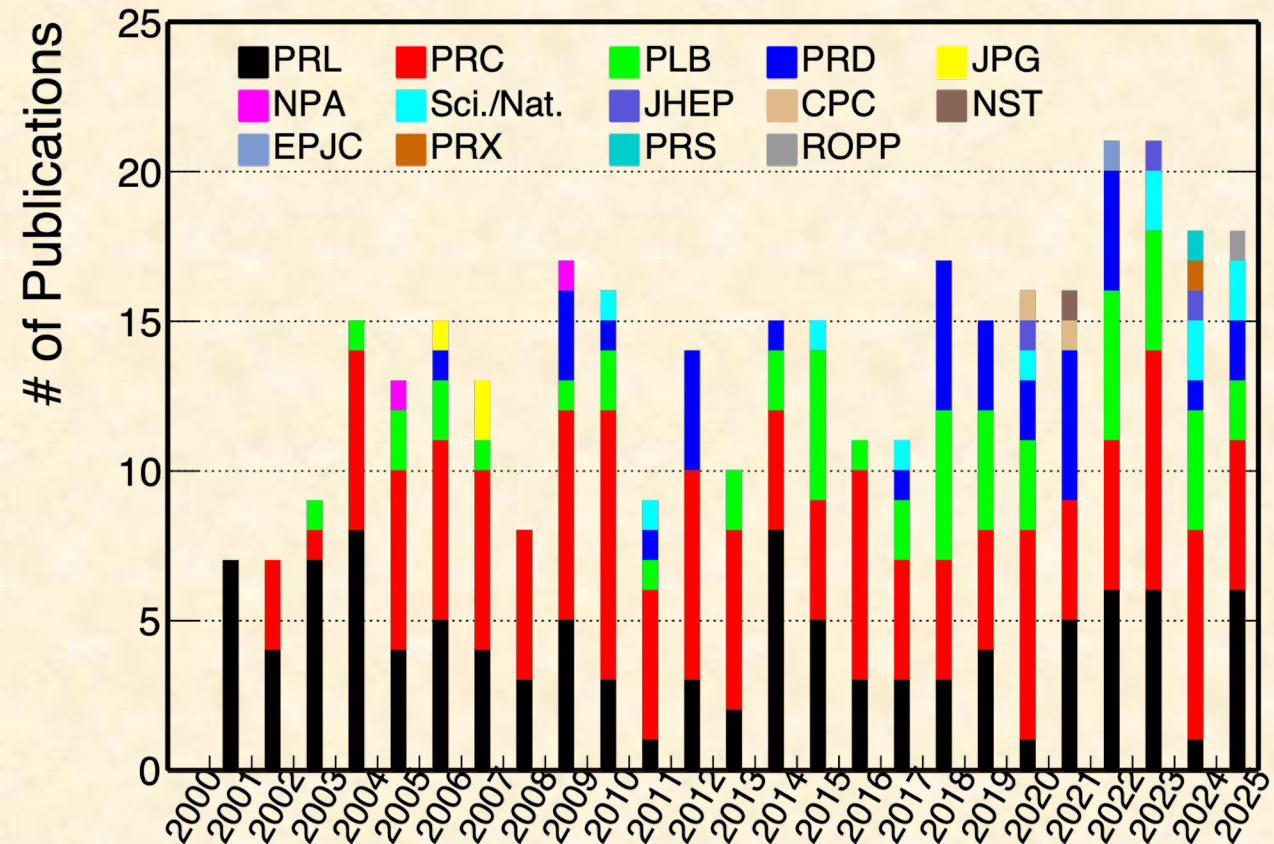


Total: 347 published physics papers

– PRL: 107, PRC: 130, PLB: 50, PRD: 34, Sci/Nat: 11, Others: 15

- STAR Theses:

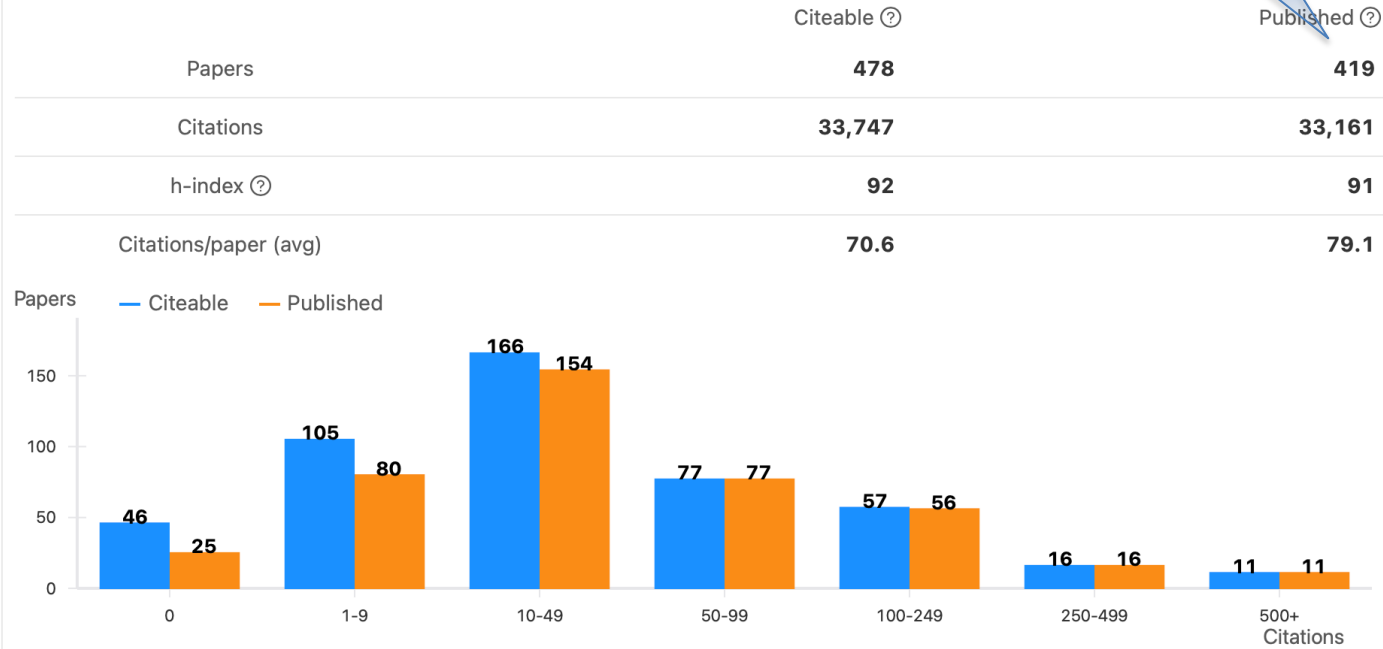
- 347 PhD theses
- 34 MS theses
- 10 Diploma theses



STAR Impact

Citation Summary

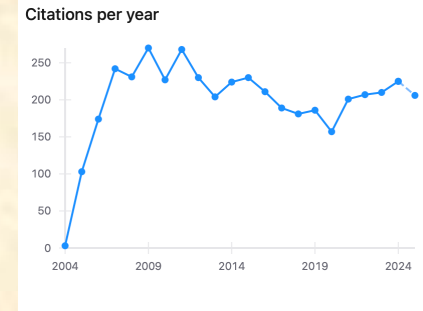
☒ Exclude self-citations ⓘ



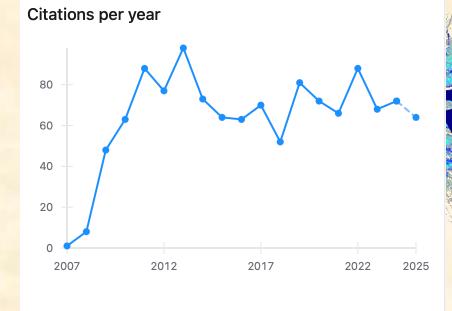
Includes ~60 few-author papers

src: INSPIRE

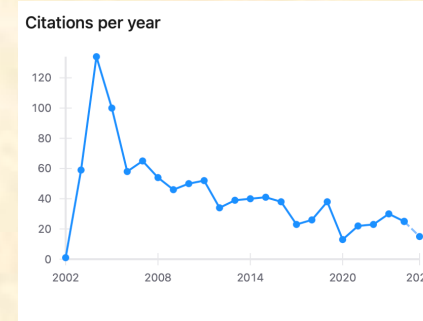
- 1000+ citations :: 4 papers
 - STAR white paper - 4379 citations
- 900 – 1000 citations :: 4 papers
 - Including NIM-A STAR Detector Overview



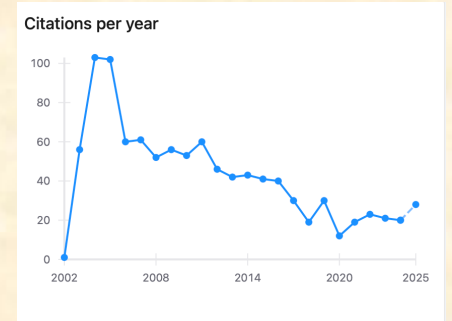
White Paper - NPA 2005



BES 1 Spectra - PRC 2009

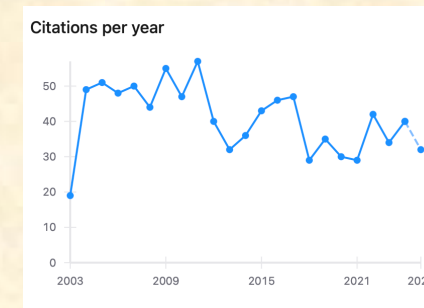


R_{dA} 200 GeV - PRL 2003

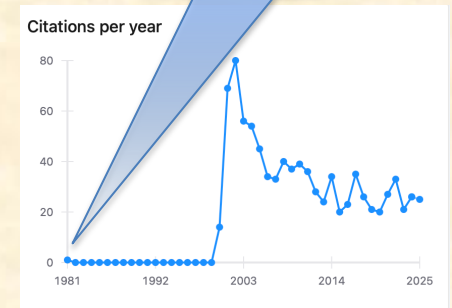


R_{AA} 200 GeV - PRL 2003

src: INSPIRE



STAR Detector – NIM-A 2002

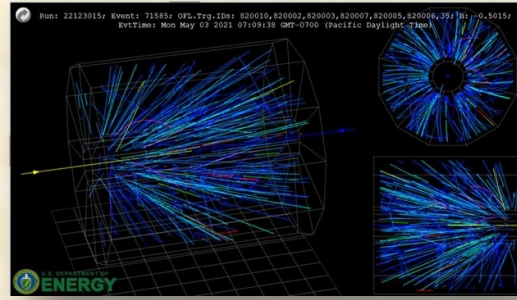


V_2 130 GeV - PRL 2001

One citation in 1981 ...

Recent DOE Office of Science NP Highlights

December 6, 2022



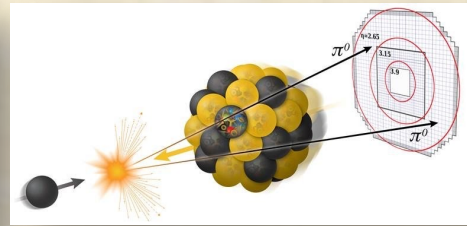
Scientists Narrow the Anchor Point in a Quantum Chromodynamics Critical Point Search

March 22, 2023



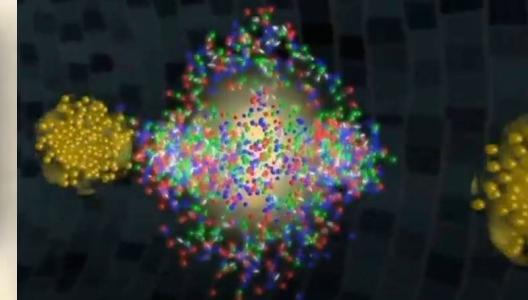
New Type of Entanglement Lets Scientists 'See' Inside Nuclei

March 24, 2023



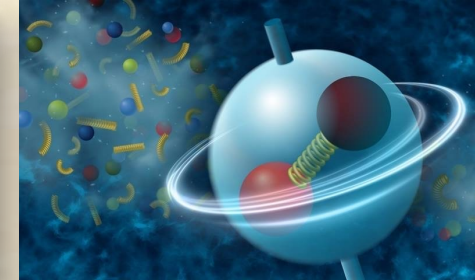
Signs of Gluon Saturation Emerge from Particle Collisions

April 7, 2023



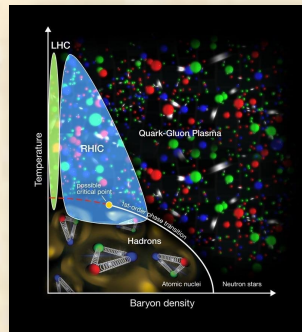
New Findings on the Flow of Particles in Heavy Ion Collisions

May 5, 2023



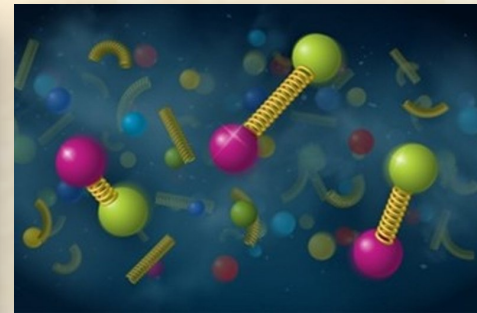
Surprising Preference in Particle Spin Alignment

June 5, 2023



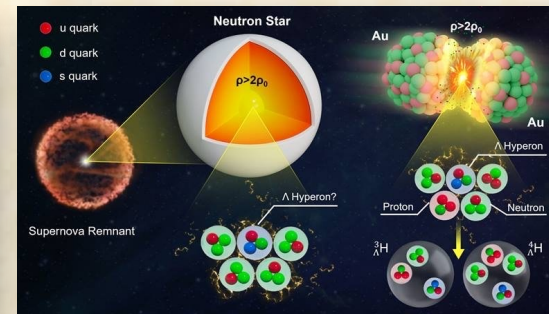
A Low-Energy 'Off Switch' for Quark-Gluon Plasma

June 15, 2023



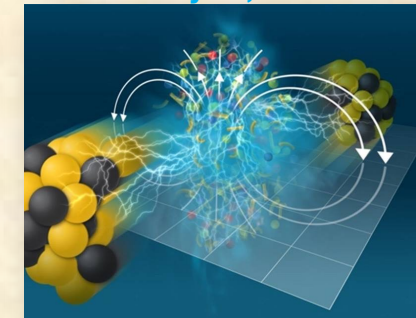
STAR Physicists Track Sequential 'Melting' of Upsiplons

August 21, 2023



New Insights into How Strange Matter Interacts with Ordinary Matter

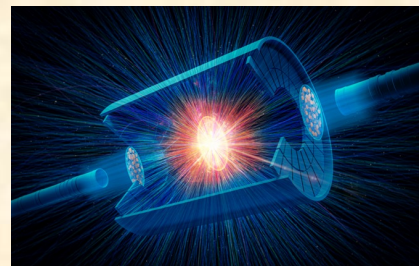
May 17, 2024



STAR Sees a Magnetic Imprint on Deconfined Nuclear Matter

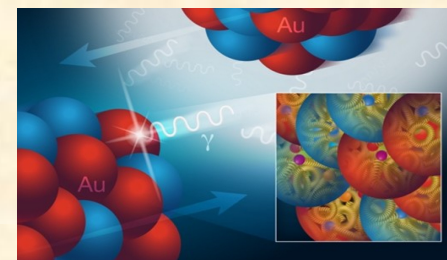
April 7, 2025

Imaging Nuclear Shapes by Smashing Them to Smithereens

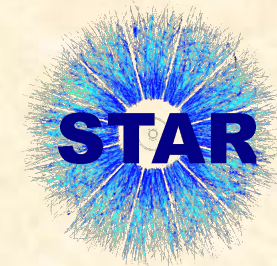


April 14, 2025

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



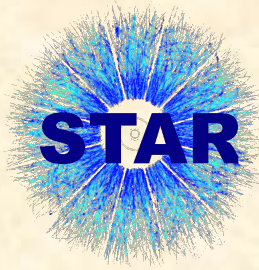
A Pipeline of Future Publications



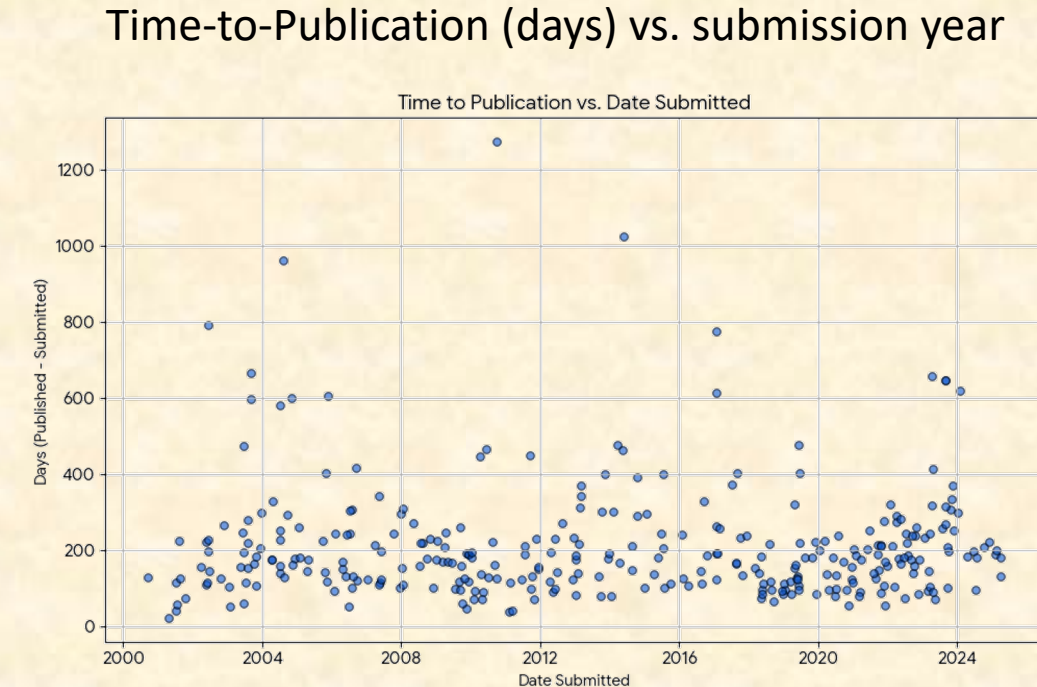
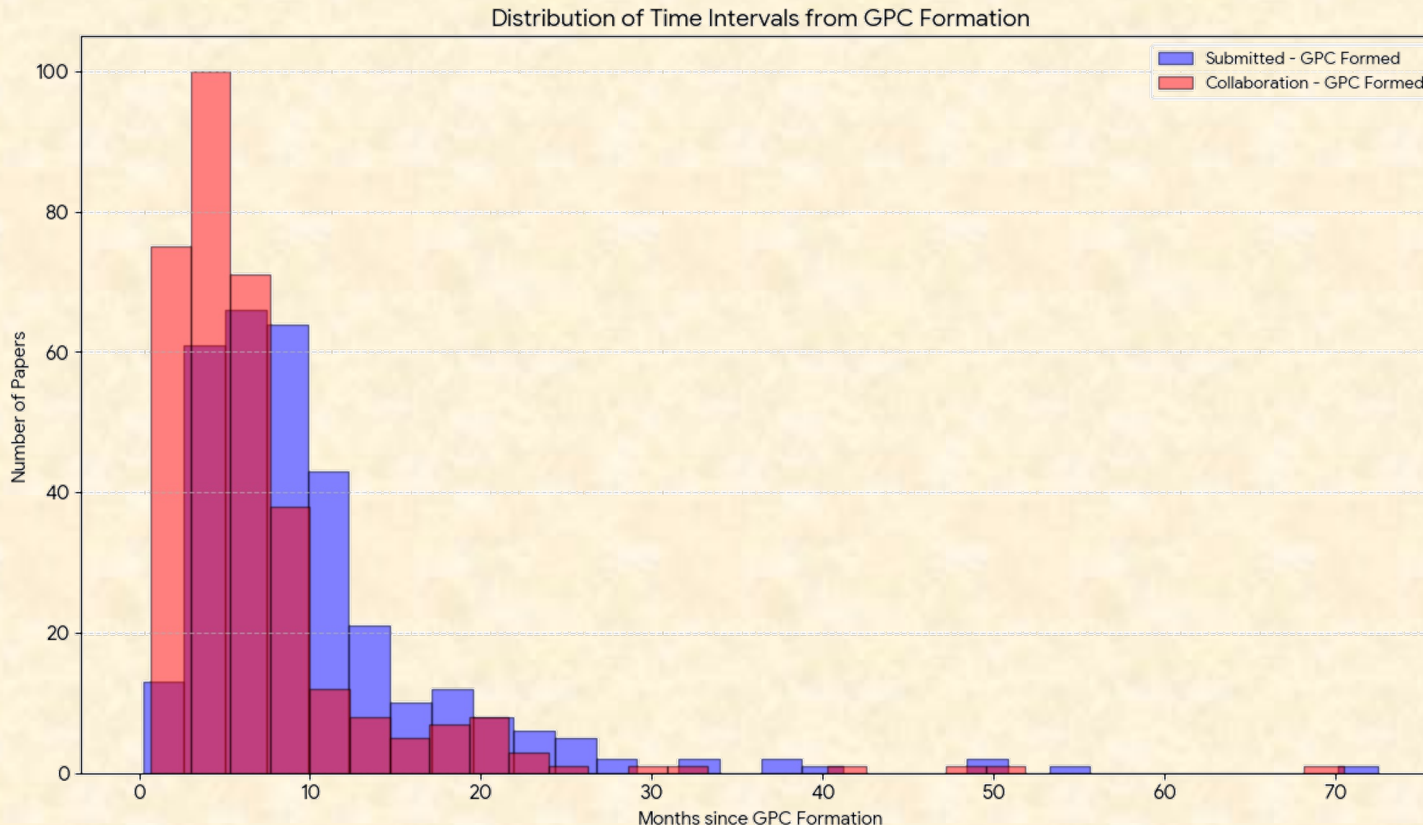
- 51 Active GPCs
 - ColdQCD - 4, CF - 9, FCV - 12, HP - 13, LFSUPC - 13
 - Papers submitted, in journal review - 16 [2, 3, 5, 2, 4]
 - Papers in collaboration review - 4 [0, 0, 1, 2, 1]
 - Papers before release to collaboration - 31 [1, 6, 6, 10, 8]
 - 33 new GPCs formed in 2025 (CQ - 3, CF - 7, FCV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

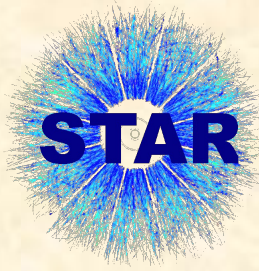


- From GPC formation to Collaboration review: mode \sim 3-4 months
- From GPC formation to Journal Submission: mode \sim 7-8 months
 - collaboration review = 2 weeks
 - final version review (1wk) + RHIC announcement (5 days) = 2wks



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

Where are we now?



Internally proposed abstracts:

QM23: 86 proposed

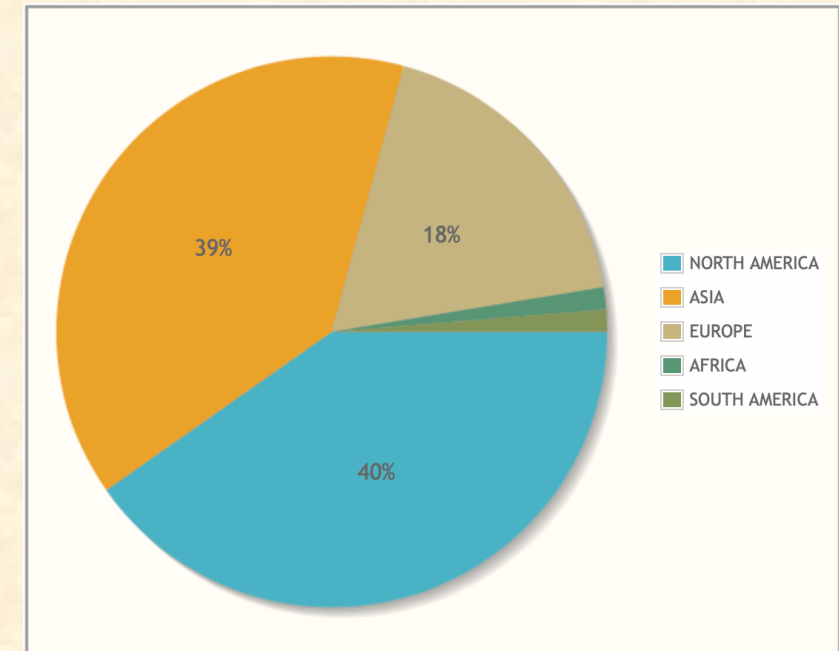
QM25: 84 proposed

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

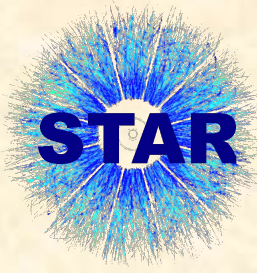
➤ **STAR is a young collaboration!**

- *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

STAR institutions



Post-Operations Era



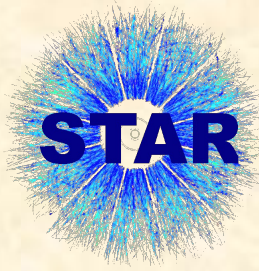
- Monday Dec.8: the last year of operations concluded
- Next year : transition to post-ops
- Next years : continued strong science output

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

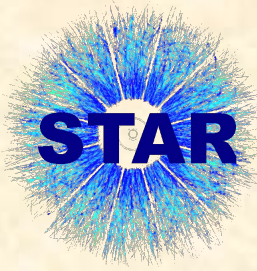
- advise on post-ops authorship rules
- adjust publication policies
- initiate service-tasks standing committee

➤ Ask your Council Rep





- Central role in operations and reconstruction
 - critical to STAR's future
- Increasing complexity
 - more subdetectors \Rightarrow increasingly larger code base
 - more data \Rightarrow 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: $7.5\text{B} + 1.9\text{B} + 9.2\text{B} = 18.6\text{B}$ (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

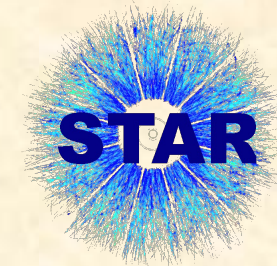
Bountiful Physics Program ahead

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/ψ 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/ψ 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
ρ^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
$\gamma_{Dir} + \text{jet } I_{AA}$	6) Jet quenching	HP	Luminosity	BEMC, EEMC FCS	BHT
$\gamma_{Dir} + \text{jet acopl.}$	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

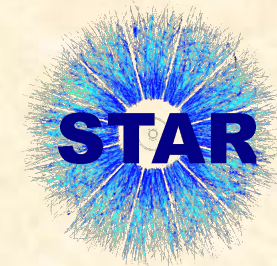
BUR 2025, STAR Note 850

Data & Analysis Preservation



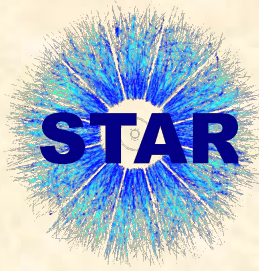
- work closely with BNL for common strategies
 - RHIC DAPP initiative successfully completed recent external review (July 1, '25)
- proactively engage with partners at BNL (SCDF, ITD, NPPS) and outside BNL (HEPdata)
 - improve accessibility to mailing lists hosted on SYMPA (ITD)
 - upgrade Drupal and 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



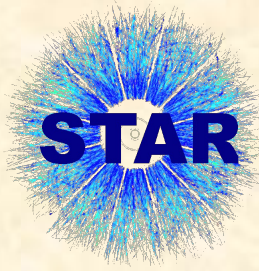
To recognize and honor
outstanding early career members
for their work and dedication to
service tasks.

2025 Awardees



« Don't forget to nominate! »

APS DNP Community Townhall Meeting



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 TBD
		13:10 - 13:25
	Nuclear Structure, Reactions and Astrophysics	Ani Aprahamian
		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 Leshar
		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

- 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

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!

