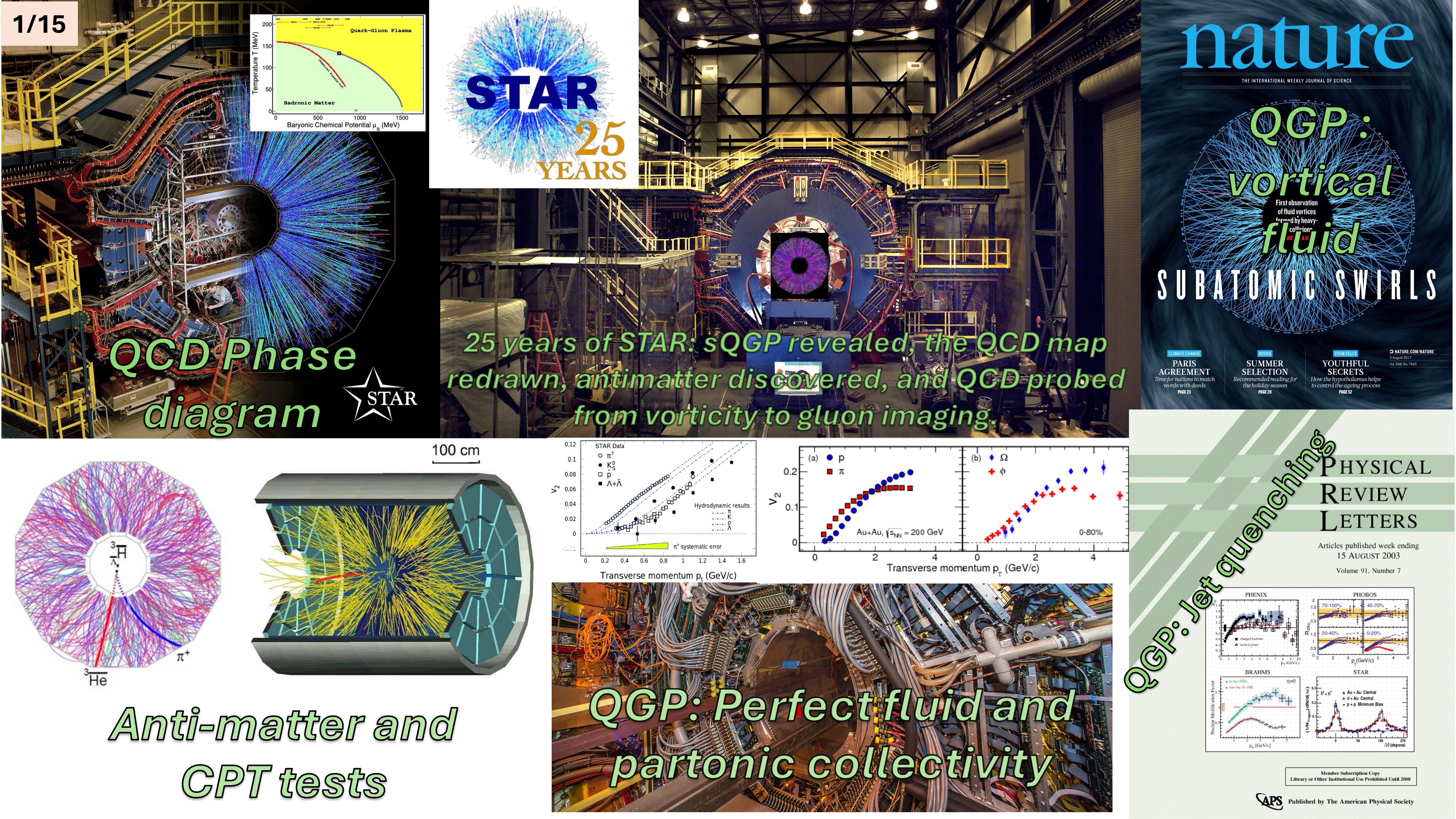

Quark-Gluon Plasma
Hadronic Matter
Temperature T (MeV)
Baryonic Chemical Potential μ_B (MeV)
STAR
25 YEARS
nature
THE INTERNATIONAL WEEKLY JOURNAL OF SCIENCE
QGP: vortical fluid
SUBATOMIC SWIRLS
PARIS AGREEMENT
SUMMER SELECTION
YOUTHFUL SECRETS
QCD Phase diagram
STAR
25 years of STAR: sQGP revealed, the QCD map redrawn, antimatter discovered, and QCD probed from vorticity to gluon imaging.
100 cm
$^3\bar{\Lambda}\bar{H}$
$^3\overline{He}$
π^+
STAR Data
Hydrodynamic results
π^+ systematic error
Transverse momentum p_t (GeV/c)
v_2
Au+Au, $\sqrt{s_{NN}}$ = 200 GeV
0-80%
Transverse momentum p_T (GeV/c)
PHYSICAL REVIEW LETTERS
Articles published week ending 15 AUGUST 2003
Volume 91, Number 7
PHENIX
PHOBOS
BRAHMS
STAR
QGP: Jet quenching
Anti-matter and CPT tests
QGP: Perfect fluid and partonic collectivity
Published by The American Physical Society

Indian Participation in STAR

NISER, Jatni

IISER Berhampur

University of Rajasthan, Jaipur

Indian Institute of Technology, Bombay

IISER Tirupati

IIT Patna

University of Jammu, Jammu

VECC, Kolkata

IOP, Bhubaneswar

NIT Durgapur

Panchayat College, Bargarh

Panjab University, Chandigarh

LPU, Punjab

Bedanga Mohanty
*NISER, **INDIA**, 17 Dec 2025*

Indian Participation in STAR

It all formally started

[1]In continuation of the proposal Submitted in ***July 1994*** *and in* ***October 1996***

VECC/EXP/QGP/97-04
STARNOTEΔ#310ΔOct. 1997

PHOTON MULTIPLICITY MEASUREMENTS IN THE STAR DETECTOR AT RHIC

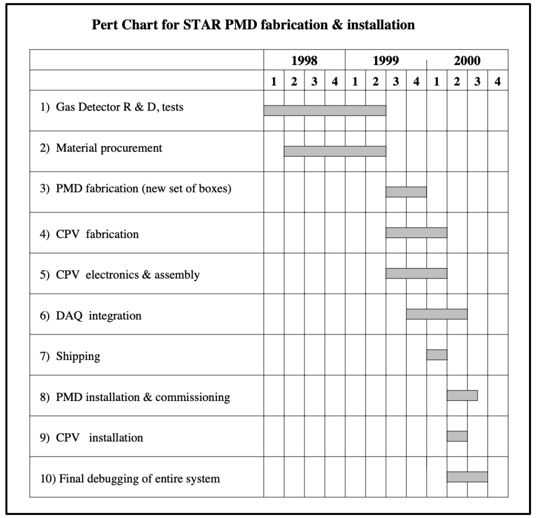
A Proposal for Upgrade of STAR[1]

Bhubaneswar - Calcutta - Chandigarh - Jaipur - Jammu - Mumbai

Science goals

It is proposed to integrate the WA98 preshower Photon Multiplicity Detector (PMD) with some modifications into the STAR experiment to study photon production and isospin fluctuations in nucleus-nucleus collisions at RHIC energy in order to investigate the formation of Quark-Gluon Plasma (QGP), the dynamics of hadronization process, the characteristics of the hot hadron gas and to search for Disoriented Chiral Condensates (DCCs). The PMD, to be mounted at 7 m from vertex, will have fine granularity and almost full azimuthal coverage in the pseudo-rapidity region $2.0 \leq \eta \leq 3.8$. Simulation results are presented to describe the effectiveness of the proposed detector to measure photon multiplicity on event–by–event basis in the actual environment of the STAR experiment. Background problems caused by material in front of the PMD are also investigated and the efforts to reduce the background by implementing a charged particle veto are described. Coupled with the Forward TPC measuring charged particles, the PMD should become an ideal tool to search for any physical processes leading to charge–neutral fluctuations. In the given environment one can achieve photon counting efficiency of better than 65% and the associated background from all sources amount to less than 35%. The event-to-event fluctuation of the measured N_γ/N_{ch} ratio will be better than 10%. We show that the PMD can provide reasonable selection on low p_T photons suitable for DCC searches and also estimates of global transverse electromagnetic energy.

Timeline



[2]Only permanent members are list. In addition, there are several graduate students

List of Collaborators[2]

Institute of Physics, Bhubaneswar
D.P. Mahapatra, S.C. Phatak

Variable Energy Cyclotron Centre, Calcutta
S. Chattopadhyay, M.R. Dutta Mazumdar, Murthy S. Ganti, T.K. Nayak, S. Ramanarain, Bikash Sinha, M.D. Trivedi, Y.P. Viyogi[3]

Panjab University, Chandigarh
M.M. Aggarwal, V.S. Bhatia

University of Rajasthan, Jaipur
K.B. Bhalla, V. Kumar, R. Raniwala, S. Raniwala

University of Jammu, Jammu
P.V.K.S. Baba, S.K. Badyal, N.K. Rao, S.S. Sambyal

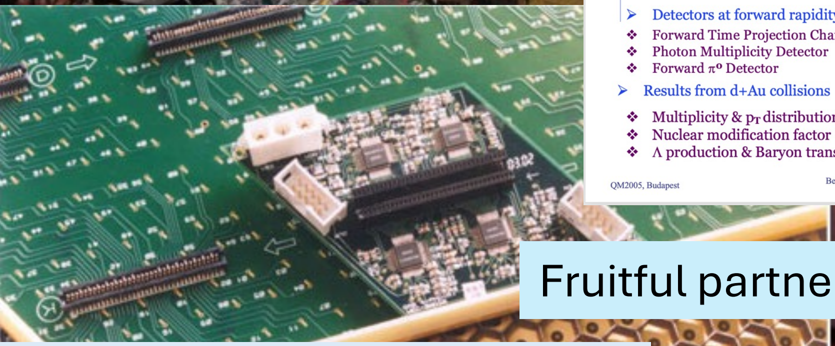
Indian Institute of Technology, Mumbai
R. Varma

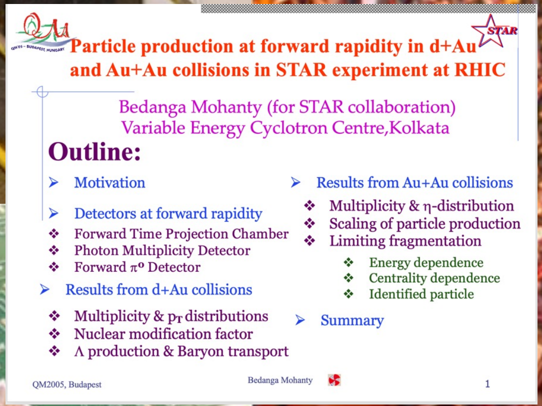
6 to 13

Due to some geo-political reasons .... we waited ...... till **.. 2001**
First contacts – John Harris, Tim Hallman, Hans Georg Ritter, Bill Christe and Pavel Neveski .....

The Photon Multiplicity Detector (PMD) was finally **installed** in the STAR experiment at Brookhaven National Laboratory (BNL) in **2003**. The device was used to detect forward inclusive photons during data collection and was **operational until 2011.**

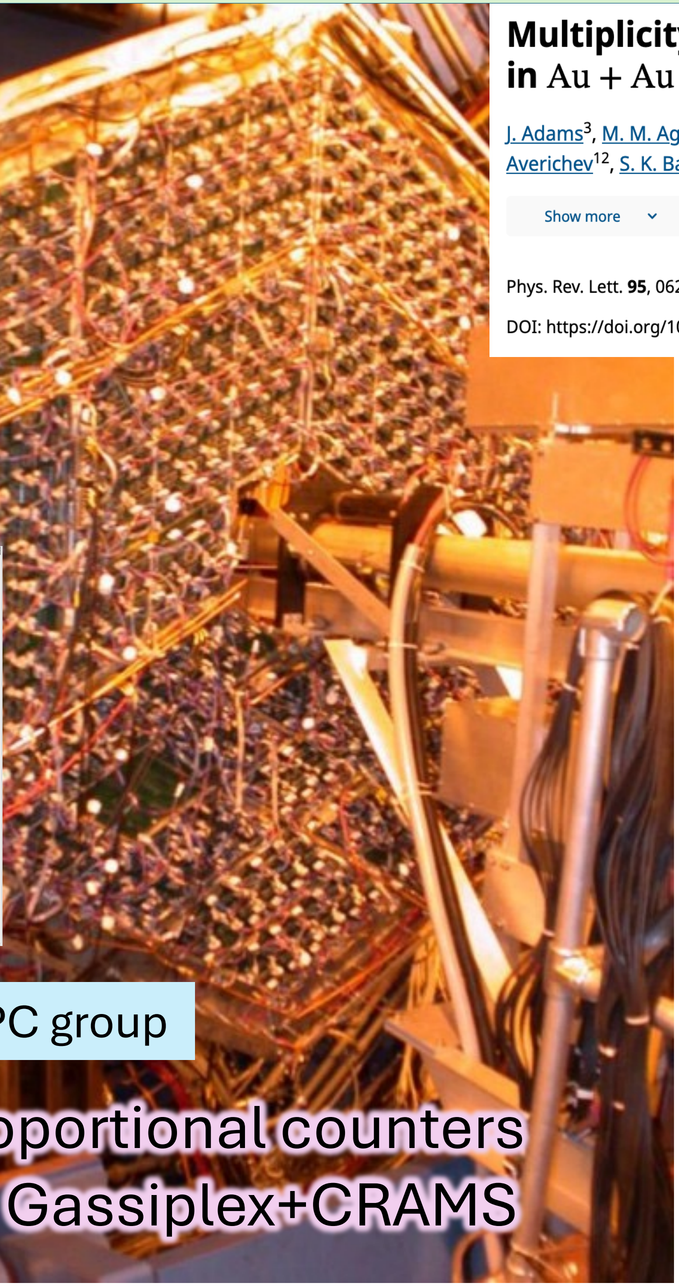
Photon Multiplicity Detector





Fruitful partnership with FTPC group

82944 proportional counters
Readout: Gassiplex+CRAMS



Multiplicity and Pseudorapidity Distributions of Photons in Au + Au Collisions at $\sqrt{s_{NN}} = 62.4$ GeV

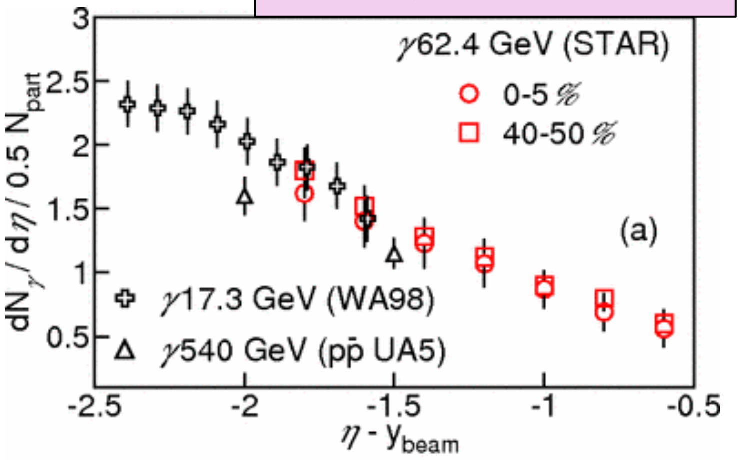
J. Adams[3], M. M. Aggarwal[29], Z. Ahammed[43], J. Amonett[20], B. D. Anderson[20], D. Arkhipkin[13], G. S. Averichev[12], S. K. Badyal[19], Y. Bai[27] *et al.* (STAR Collaboration)

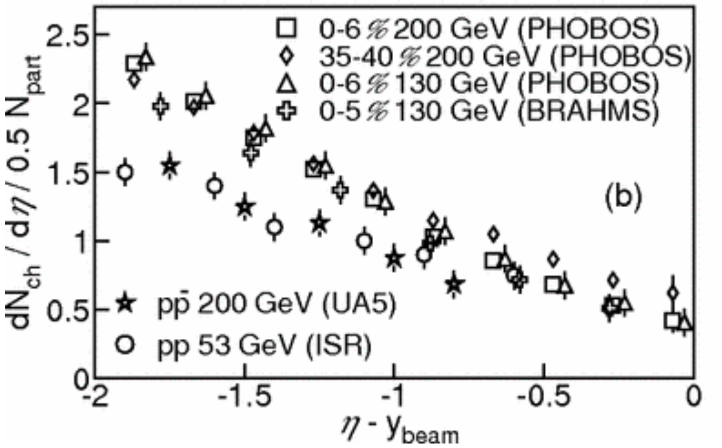
Show more

Phys. Rev. Lett. **95**, 062301 – **Published 5 August, 2005**

DOI: https://doi.org/10.1103/PhysRevLett.95.062301

First identified particle longitudinal scaling at RHIC





Phys.Rev.Lett. 95 (2005) 062301
Phys.Rev.C 73 (2006) 034906
Nucl.Phys.A 832 (2010) 134-147
Phys.Rev.C 91 (2015) 3, 034905
Nucl.Instrum.Meth.A 499 (2003) 751-761

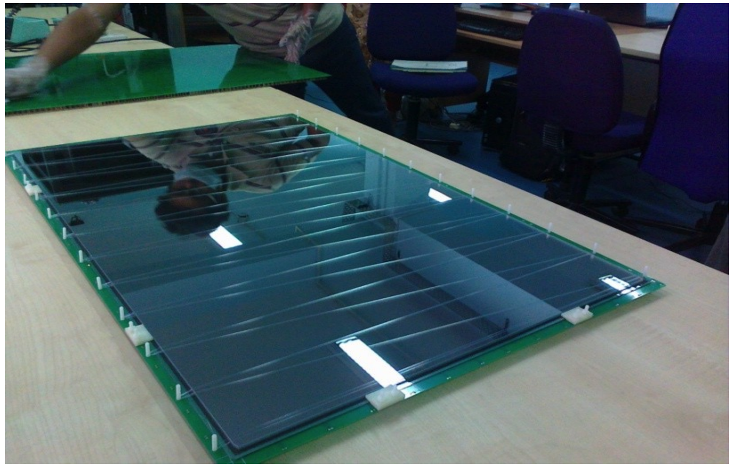
Muon Telescope Detector

Contribution: ~10% (12 out of 120) modules of the MRPC modules in STAR-MTD.

First batch delivered in June 2013

Pick-up strip

Graphite coated outer glass

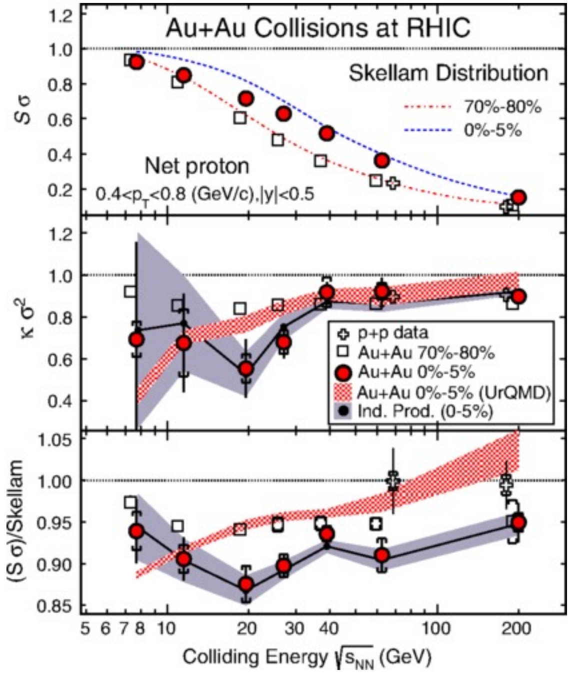


250 μm Fishing lines

Major Science Contributions

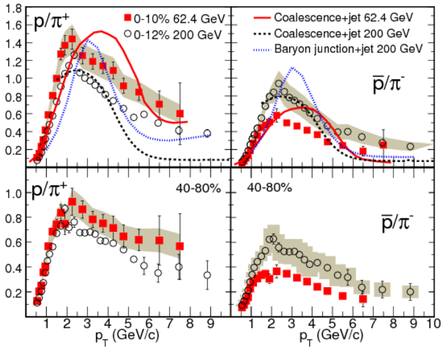
(Selected list, jointly with others)

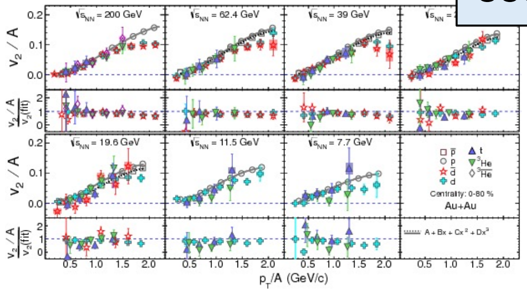
Critical Point Search
(Phys.Rev.Lett. 112 (2014) 032302; 597 citations)

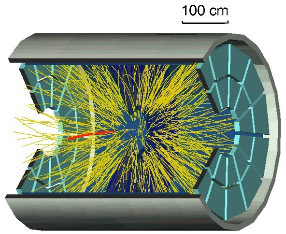


Defining the observable to making measurements

Baryon-to-meson enhancement
(Physics Letters B 655 (2007)104-113; 244 citations)

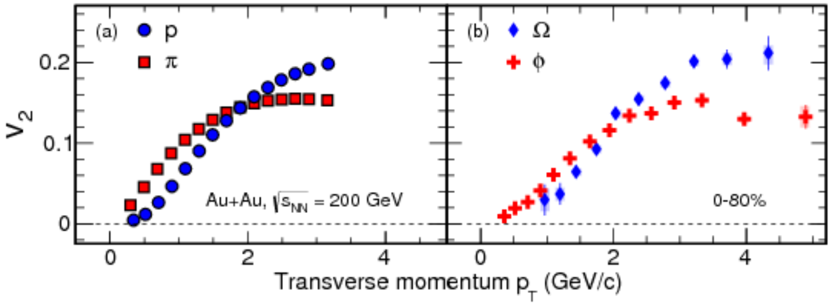




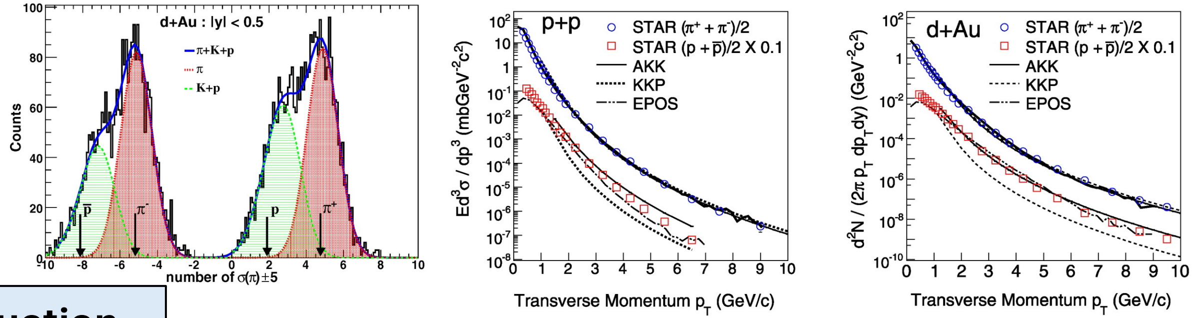


Nuclei production
(Phys. Rev.C 94 (2016) 3, 034908, 103 citations;
Nature 473 (2011) 353, 219 citations)

Partonic Collectivity
(Phys. Rev. Lett. 116 (2016) , 062301,110 citations)

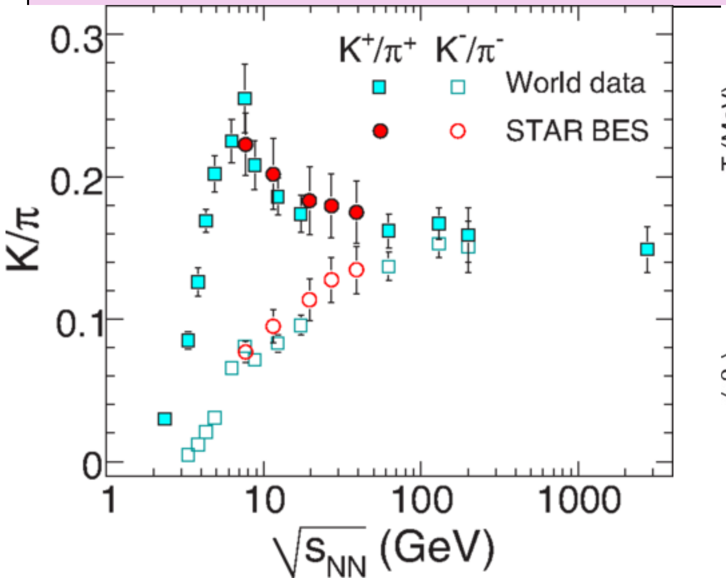


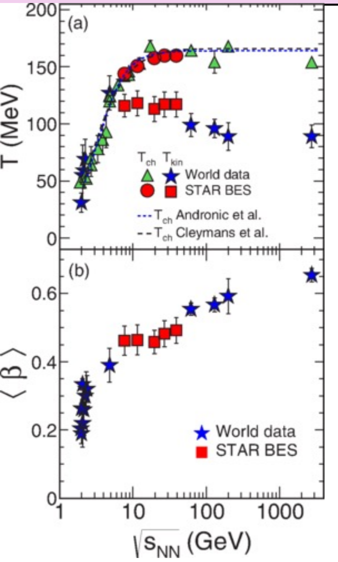
Relativistic rise of dE/dx measured in TPC to identify hadrons at ***high p_T and test of pQCD***
(_Phys.Lett.B_ 637 (2006) 161-169, 368 citations)



Thanks to STAR and collaborators for the opportunity

Bulk properties and Freeze-out dynamics
(_Phys.Rev.C_ 96 (2017) 4, 044904; 767 citations)





PhD students and impact from/in India

Name (Area, Year)	Currently (Experiment)
Anand Kumar Dubey (Detector, 2004)	Faculty at VECC, Kolkata (CBM)
Supriya Das (K/pi fluctuations, 2005)	Faculty at Bose Institute (CBM, ALICE)
Dipak Kumar Mishra (Resonance, 2006)	Faculty at BARC, Mumbai (PHENIX and CMS)
Raghunath Sahoo (E_T 2007)	Faculty at IIT Indore (ALICE)
Pawan K. Netrakanti (PMD, Spectra, 2008)	Faculty at BARC, Mumbai (CMS and Neutrino)
Debasish Das (HBT, 2008)	Faculty at SINP, Kolkata (ALICE)
Sunil M. Dogra (DCC, 2009)	Faculty at Kyungpook National University (CMS)
Lokesh Kumar (spectra and p_T fluc, 2010)	Faculty at Panjab University (STAR and ALICE)
Sadhana Dash (resonance, 2010)	Faculty at IIT Bombay (ALICE, EPIC)

Selected list here

40

Driving scientific program in our field in India

Name (Area, Year)	Currently (Experiment)
Mriganka M. Mondal (jets, 2011)	Faculty at LPU, Panjab (STAR, EPIC)
Navneet K. Pruthi (v_3 2011)	Faculty at DAV College, Chandigarh (STAR)
Chitrasen Jena (nuclei, 2012)	Faculty at IISER Tirupati (STAR, EPIC)
Prabhat Kumar Pujahari (rho-meson, 2012)	Faculty at IIT Madras (CMS, EPIC)
Nihar Ranjan Sahoo (fluctuations, 2013)	Faculty at IISER Tirupati (STAR)
Prithwish Tribedy (DCC, 2014)	Faculty at Brookhaven National Laboratory, USA (STAR)
Md. Nasim (flow, 2014)	Faculty at IISER Berhampur (STAR, EPIC)
Rihan Haque (nuclei flow, 2015)	Faculty at Government College, WB
Sabita Das (spectra, 2015)	Faculty at K.K.S Womens College, Balasore (teaching)
Amal Sarkar (fluc, 2015)	Faculty at IIT Mandi (CMS, EPIC)
Arghya Chatterjee (fluc, 2019)	Faculty at NIT Durgapur (STAR)

Scientific leadership roles (selected)

Deputy Spokesperson (2011-2014)
Physics Analysis Coordinator (2008-2010)

GPC Member (Paper committee)	Primary Author
~85	~51
Non overlapping : GPC: ~ 21 % of STAR paper and ~ 13% of STAR published paper	

PAC – 10 hours time difference; 7800 miles

- New PWG structure
- Publication Policy – STAR Notes and codes in CVS
- Decadal Plan.
- BES Program.
- First submissions to Science and Nature journals.
- 3-QM's : 2008, 2009, 2011.
- W-spin asymmetry

Physics Working Group Convenors

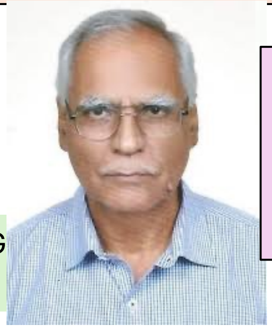
Convenor Light flavour spectra (2020-2022)

Convenor Light flavour spectra (2011-2016)

Convenor Bulk correlations (2009-2011)

Convenor Bulk correlations (2008-2009)

Convenor Spectra WG (2006-2008)



PMD project leader

STAR Talks Committee Members

(2020-2022)

(2018-2020)

(2013-2015)

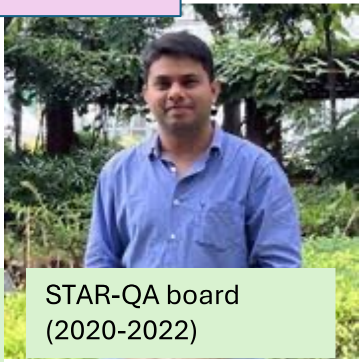
(2011-2013)

(2008-2010)

(2006-2008)

Trigger and QA Boards

Member Trigger Board (2008-2010)
Member BUR Committee (2008-2010)



STAR-QA board (2020-2022)

Role in Beam Energy Scan Program @ STAR-RHIC

STAR: Beam User Request 2008:

“Start the energy scan program within root(s_NN) = 39 - 6.1 GeV. This is to search for the QCD phase boundary and the possible critical point in the diagram.”

Nuclear & Particle Physics Program Advisory Committee – ***STAR proposal NOT accepted*** .

(A) “...the experimental capabilities, in particular at sub-injection energies (i.e. below the normal AGS injection energy), are quite different for the two experiments, due to overall acceptance and triggering issues.”

--- Demonstrate STAR (designed for 200 GeV) can run at low energy

(B) “To date, however, the PAC has not seen a compelling presentation of the key observables and their potential physics impact for this measurement program. .....observables need to be identified, their measurements simulated and luminosity requirements established.” -- ***Establish a proper observable***

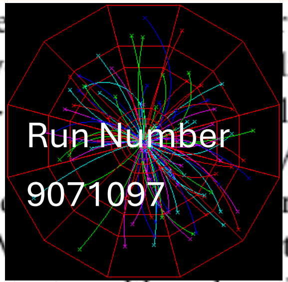
330 citations

3000 events

PHYSICAL REVIEW C **81**, 024911 (2010)

Identified particle production, azimuthal anisotropy, and interferometry measurements in Au + Au collisions at $\sqrt{s_{NN}} = 9.2$ GeV

We present the first measurements of identified hadron production, azimuthal anisotropy, and pion interferometry from Au + Au collisions below the nominal injection energy at the BNL Relativistic Heavy-Ion Collider (RHIC) facility. The data were collected using the large acceptance [...] at RHIC (STAR) detector at $\sqrt{s_{NN}} = 9.2$ GeV from a test run of the collider in the y[...]ity results on multiplicity density dN/dy in rapidity y, average transverse momentum $\langle p_T$[...]liptic flow, and Hanbury-Brown–Twiss (HBT) radii are consistent with the corresponding [...] $\sqrt{s_{NN}}$ from fixed-target experiments. Directed flow measurements are presented for both mi[...]rd-rapidity regions. Furthermore the collision centrality dependence of identified particle dN[...]ticle ratios are discussed. These results also demonstrate that the capabilities of the STAR detector, although optimized for $\sqrt{s_{NN}} = 200$ GeV, are suitable for the proposed QCD critical-point search and exploration of the QCD phase diagram at RHIC.

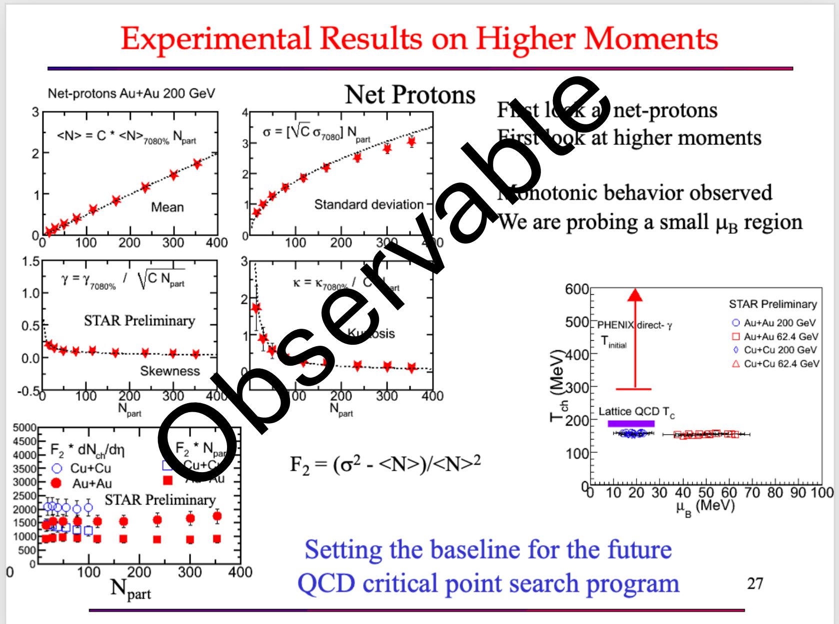


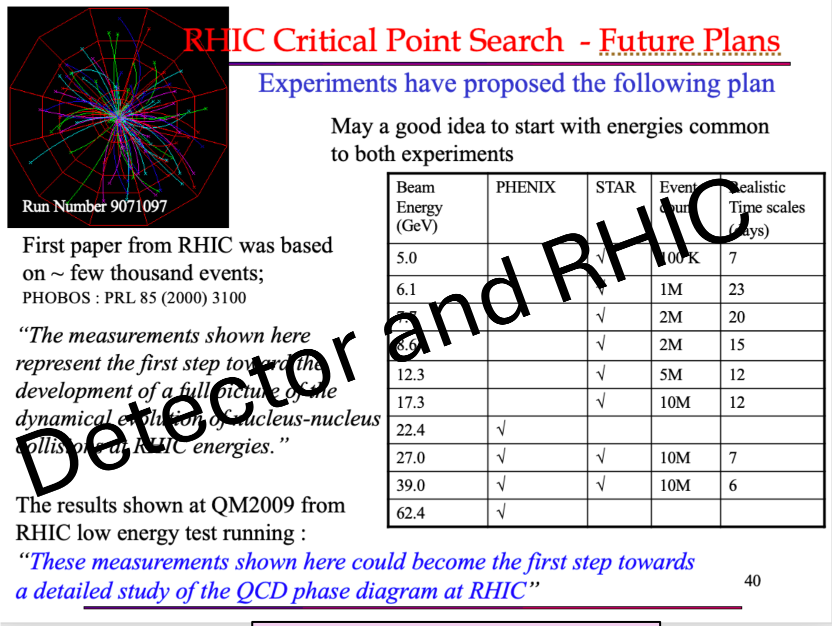
417 citations

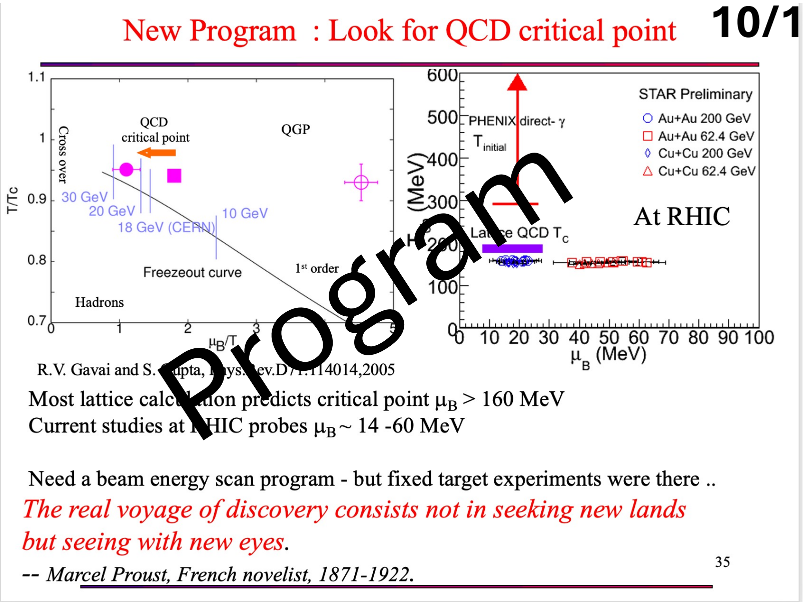
PRL **105**, 022302 (2010) PHYSICAL REVIEW LETTERS week ending 9 JULY 2010

Higher Moments of Net Proton Multiplicity Distributions at RHIC

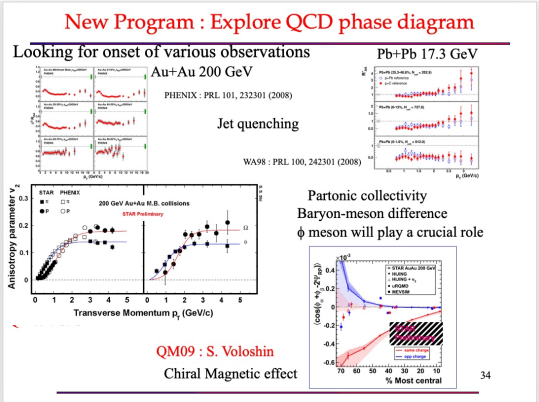
at μ_B values $\lesssim 200$ MeV in the QCD phase plane. The RHIC beam energy ($100 < \mu_B < 550$ MeV) scan will look for nonmonotonic variation of $\kappa\sigma^2$ for net protons as a function of $\sqrt{s_{NN}}$ to locate the CP.





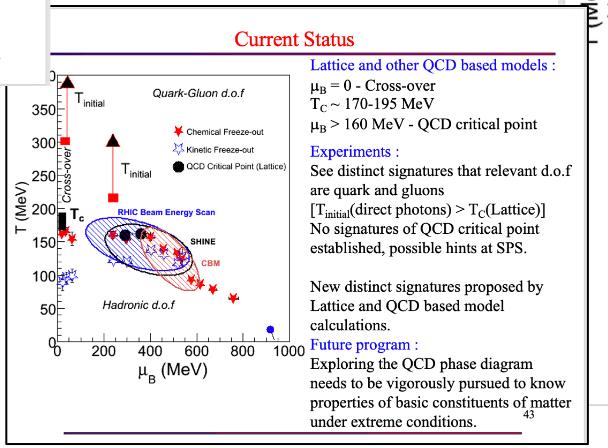


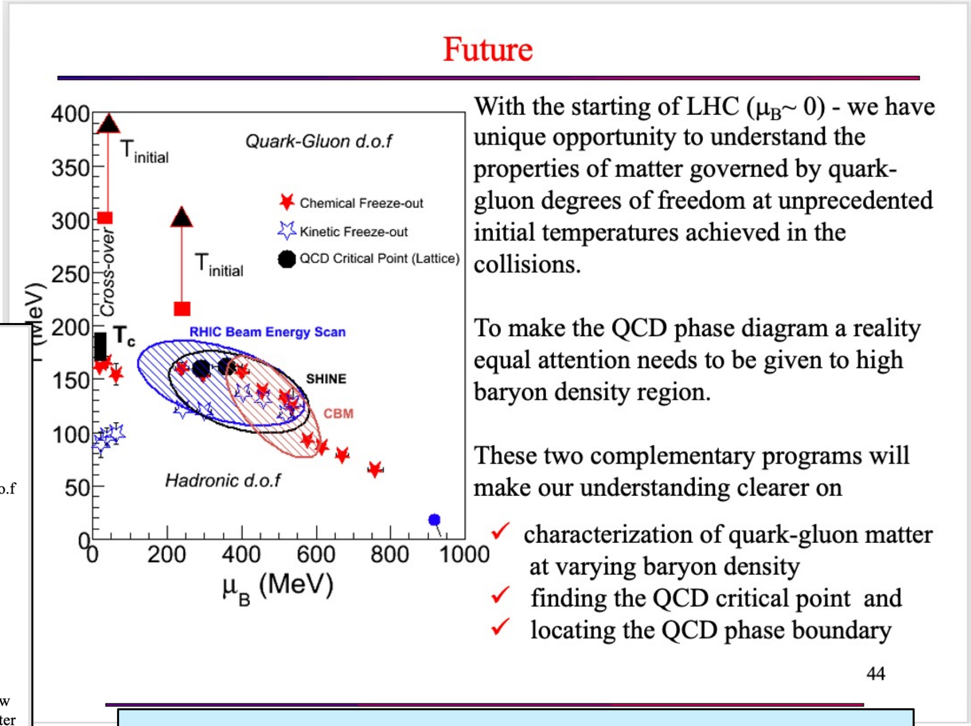
QM2009 Summary talk (March-April 2009)



Nucl. Phys. A 830 (2009) 899C-907C

Gathered the community support for BES program





Beam Energy Scan Program required

Beam Energy Scan Program @ STAR-RHIC

Experimental Study of the QCD Phase Diagram and Search for the Critical Point: Selected Arguments for the Run-10 Beam Energy Scan at RHIC. The STAR Collaboration (B. I. Abelev et al.); **Jun. 4, 2009**

"We present an overview of the main ideas that have emerged from discussions within STAR for the Beam Energy Scan (BES)."

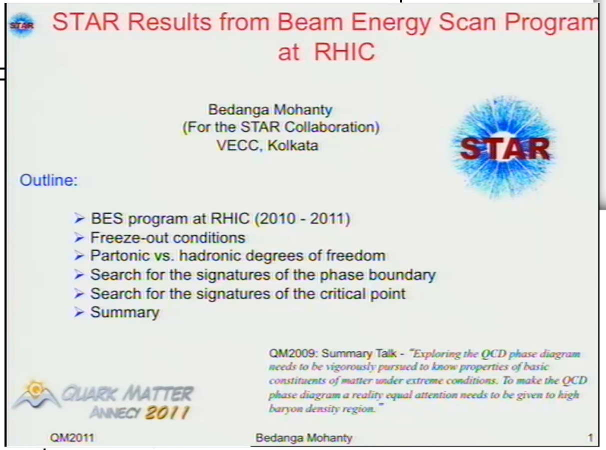
Collision Energies (GeV)		5	7.7	11.5	17.3	27	39
Section	Observables	Millions of Events Needed					
A1	n_q scaling $\pi/K/p/\Lambda$ $(m_T-m_0)/n<2$GeV	8.5	**6**	**5**	**5**	**4.5**	**4.5**
A1	ϕ/Ω up to $p_T/n_q=2$ GeV/c		56	25	**18**	**13**	**12**
A2	R_{CP} up to p_T ~4.5 GeV/c (at 17.3) 5.5 (at 27) & 6 GeV/c (at 39)				**15**	**33**	**24**
A3	untriggered ridge correlations		27	13	**8**	**6**	**6**
A4	parity violation		**5**	**5**	**5**	**5**	**5**
B1	v_2 (up to ~1.5 GeV/c)	**0.3**	**0.2**	**0.1**	**0.1**	**0.1**	**0.1**
B1	v_1	0.5	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**
B2	Azimuthally sensitive HBT	4	**4**	**3.5**	**3.5**	**3**	**3**
B3	PID fluctuations (K/π)	1	**1**	**1**	**1**	**1**	**1**
B3	net-proton kurtosis	5	**5**	**5**	**5**	**5**	**5**
B3	differential corr & fluct vs. centrality	5	**5**	**5**	**5**	**5**	**5**
B3	integrated p_T fluct (T fluct)						
See[1]:	charge-photon fluctuations (DCC)	1	**1**	**1**	**1**	**1**	**1**
	kink/step/horn	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**
	v_2 fluctuations	0.5	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**
	HBT (R_l, R_o/R_s)	0.8	**0.8**	**0.5**	**0.5**	**0.5**	**0.5**
	Jet/ridge 2<trig<4, 1<assoc<trig				30	**8.8**	**4.5**
	Jet/ridge 3<trig<6, 1.5<assoc<trig					53	**24**
	Baryon-Strangeness cor (hypernuc)						50
	Forward π^- yield (rapidity scaling)						
	Forw. $\gamma(\pi^0)$ yield (rapidity scaling)						
	Long-range forward-backward corr.						
	Other PID fluctuations (esp. K/p)						
	Particle ratios (many examples)						
	p_T spectra						
	Prod. of light nuclei & antinuclei						
	Yields of species & stat model fits						

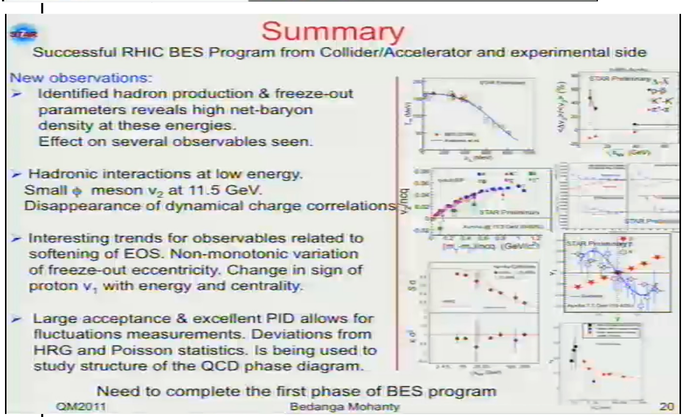
Table 2: Observables and statistics needed for the first BES run. The observables in the yellow-shaded area relate to the search for turn-off of new phenomena already established at higher RHIC energies (see section A), while observables in the blue-shaded area search for a phase transition or critical point (see section B). The numbers listed in boldface above are all within reach (nominally require no more than 1.5 times the proposed statistics) in the first BES run plan as set out in Table 1. The remaining numbers (not boldface) will need to wait for higher statistics in a subsequent run. The white part above is briefly introduced in this document, and is explained in detail in Ref. [1].

http://drupal.star.bnl.gov/STAR/starnotes/public/sn0493

15-16, June 2009, Nuclear & Particle Physics Program Advisory Committee ***recommends for Run 10 BES***

..... 12 weeks for a beam energy scan (BES) with Au-Au collisions.. ... is justified by the strong attention given in the RHIC community to the potential for a landmark observation in this energy range...... In arriving at its recommendations for the BES, the PAC has given priority to careful measurements of the energy dependence of fluctuation and correlation observables associated with the CEP search,......





https://webcast.in2p3.fr/video/star_results_from_the_beam_energy_scan_program

First results from STAR BES presented in 2011 Quark Matter, Annecy, France

Success of BES program (somes measures)

Topic	Paper	Citations
Directed, Elliptic and Triangular Flow and flow fluctuations	*Phys.Rev.C* 86 (2012) 054908 *Phys.Rev.C* 88 (2013) 014902 *Phys.Rev.Lett.* 110 (2013) 14, 142301 *Phys.Rev.Lett.* 112 (2014) 16, 162301 *Phys.Rev.C* 94 (2016) 3, 034908 *Phys.Rev.C* 93 (2016) 1, 014907 *Phys.Rev.Lett.* 116 (2016) 11, 112302 *Phys.Rev.C* 98 (2018) 3, 034918 Phys.Rev.Lett. 120 (2018) 6, 062301 *Phys.Lett.B* 784 (2018) 26-32 *Phys.Rev.C* 102 (2020) 4, 044906 *Phys.Rev.Lett.* 129 (2022) 25, 252301 *Phys.Lett.B* 839 (2023) 137755 *Phys.Lett.B* 862 (2025) 139245 *Phys.Rev.C* 111 (2025) 1, 014906	215 244 135 313 103 111 83 58 136 15 22 19 11 11 3
Fluctuations	*Phys.Rev.Lett.* 112 (2014) 032302 *Phys.Rev.Lett.* 113 (2014) 092301 *Phys.Rev.C* 92 (2015) 2, 021901 *Phys.Lett.B* 785 (2018) 551-560 *Phys.Rev.C* 100 (2019) 1, 014902, *Phys.Rev.C* 102 (2020) 2, 024903 *Phys.Rev.Lett.* 126 (2021) 9, 092301, *Phys.Rev.C* 104 (2021) 2, 024902 *Phys.Rev.Lett.* 127 (2021) 26, 262301 *Phys.Rev.Lett.* 130 (2023) 8, 082301, *Phys.Rev.Lett.* 135 (2025) 14, 142301	597 396 34 168 58 30 340 192 67 54 40
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Topic	Paper	Citations
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Kept STAR physics running and community active for another decade

PRL ~ 14; Nature group ~ 3; Citations ~ 7098

STAR: A truly *international* experiment with one of the finest detectors at an exceptional facility (RHIC)

Deep scientific discoveries

1. Recreated early-universe temperature and matter conditions in the laboratory.
2. Formed the Quark–Gluon Plasma, measured its properties — e.g., viscosity, vorticity — at unprecedented values.
3. Made foundational contributions to mapping the QCD phase diagram.
4. Discovered never-before-seen anti-matter nuclei.
5. Explored novel QCD phenomena across a remarkable range of possibilities.
6. Enabled the development of relativistic magneto-spin hydrodynamics through precision measurements.
7. Found that gluons provide a significant share of the proton's spin.

25 years, countless collisions, one extraordinary legacy

1. We turned microseconds after the Big Bang into measurable reality.
2. We found antimatter born anew.
3. We mapped a phase space once thought unreachable.
4. We tested ideas that may yet change textbooks.

"I am reminded of a famous remark of Napoleon. Whenever he was presented with a young man for military advancement, he invariably asked the question: Is he lucky?
This was by no means a casual inquiry. The important quality for which he was seeking was does this man put himself in a situation where he can be lucky? If you fail to put yourself in a situation where it is possible to have good fortune then you cannot have any success; if you do, you may.
-- Powell in after dinner talk at St. Cergue after-may."

STAR has been lucky — because its people have been creative. Express our gratitude for the privilege of being part of this extraordinary chapter.

Glimpse of STAR-India in past few years


STAR-India 2018

STAR-India 2016

STAR-India 2023

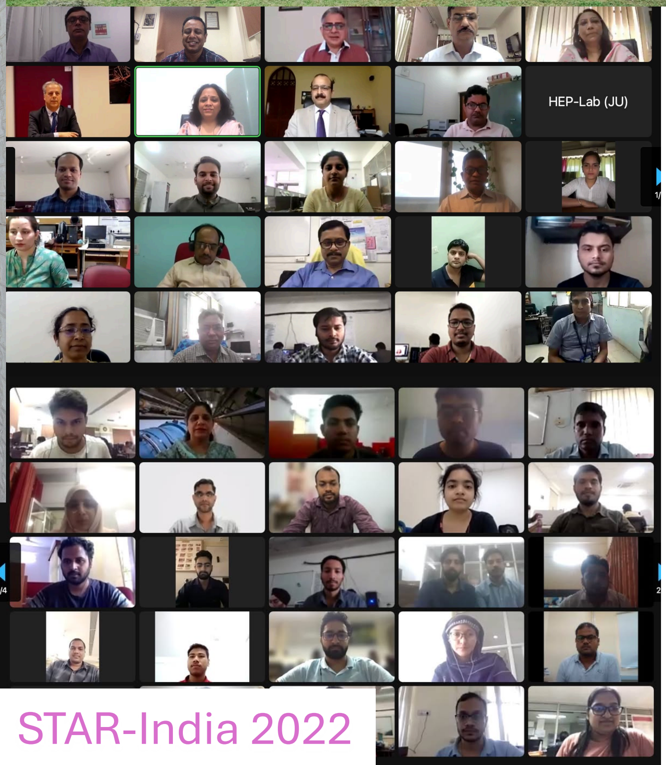
STAR-India 2024

STAR-Counting hall – 9.2 GeV data taking

STAR-India 2021

STAR-India 2022

STAR-India 2024



STAR-India 2022



The STAR experiment

at the Relativistic Heavy Ion Collider, Brookhaven National Laboratory

QM2025

Thank you

QM2006

Truly an international enterprise