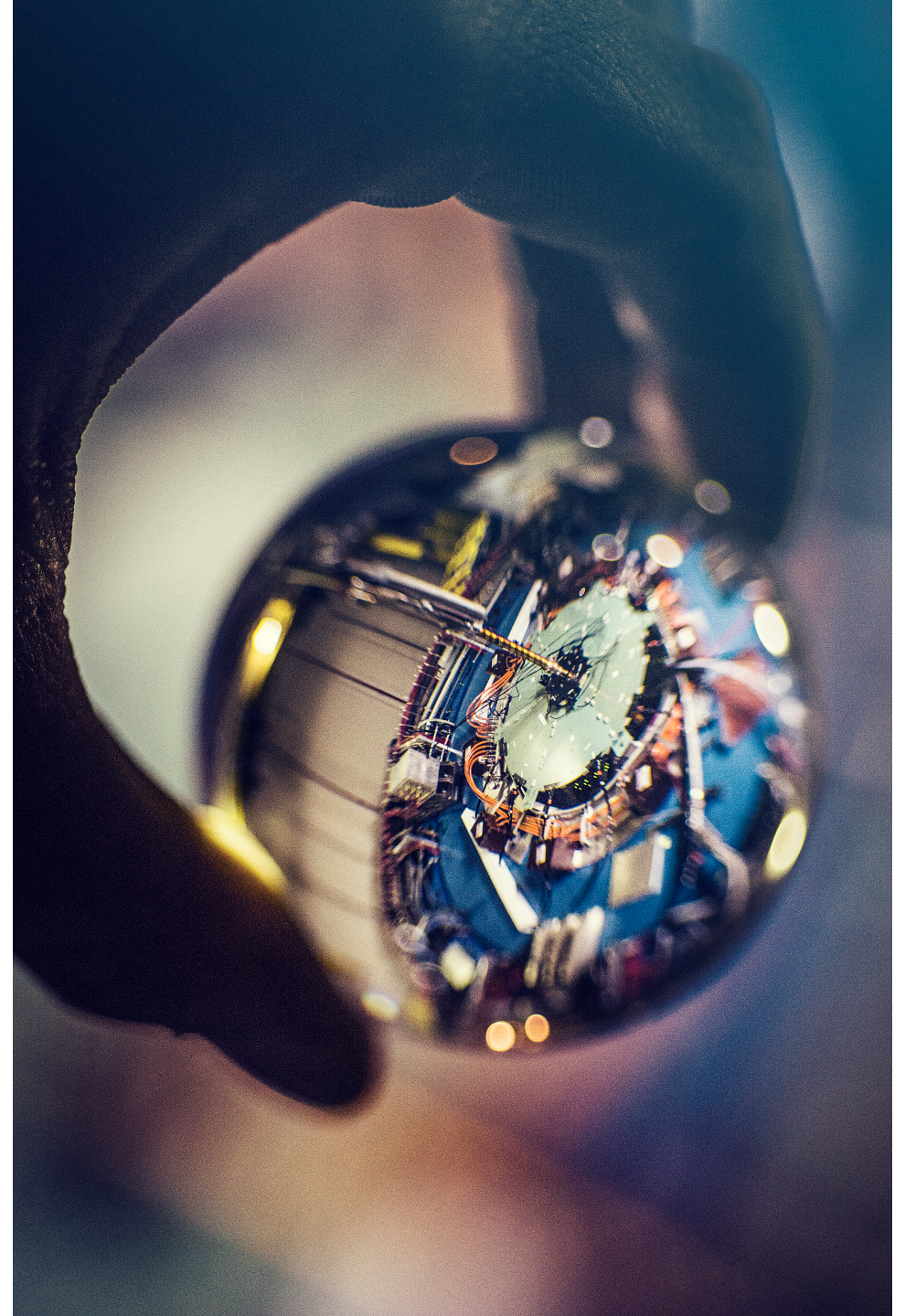


STAR Upgrade and long-term plan

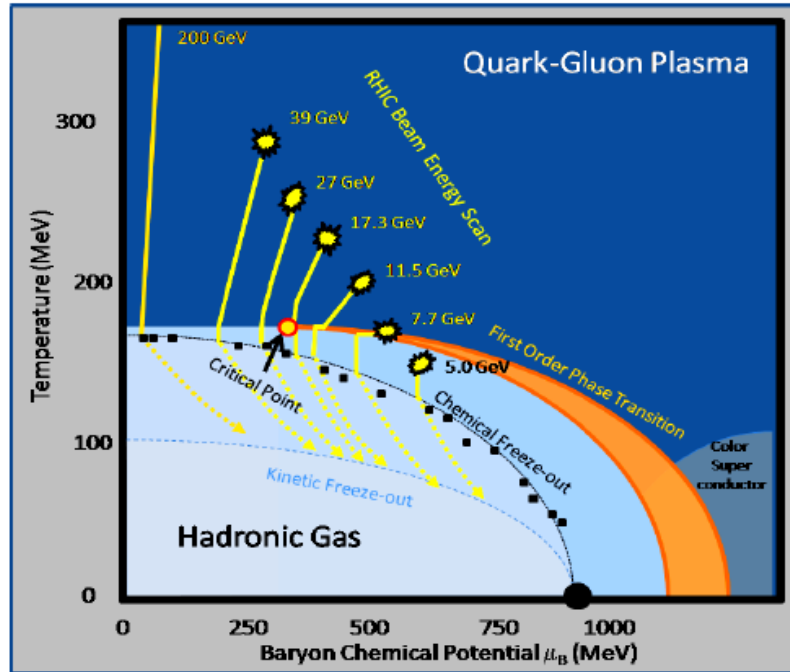
Zhangbu Xu



The history of our forward upgrade Planning
starting from the Decadal Plan.

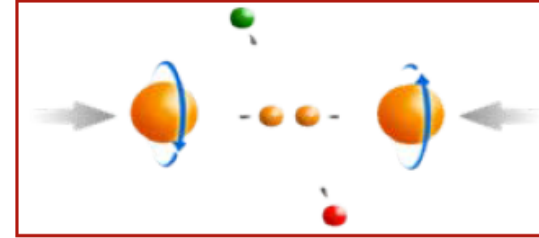
RHIC: eight key unanswered questions

Hot QCD Matter

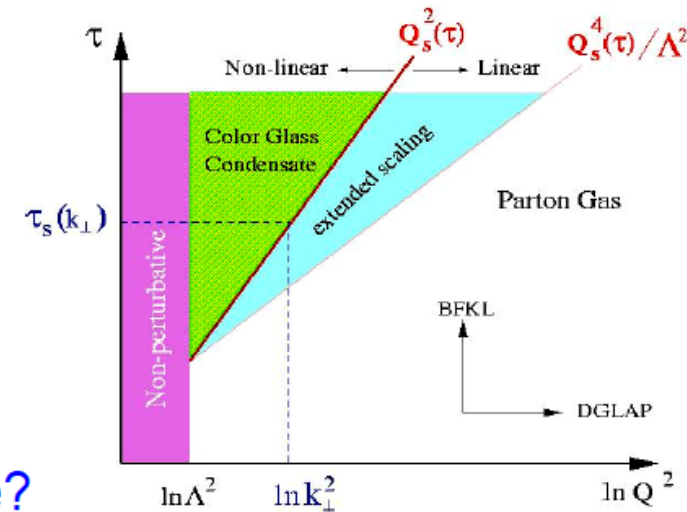


- 1: Properties of the sQGP
- 2: Mechanism of energy loss: weak or strong coupling?
- 3: Is there a critical point, and if so, where?
- 4: Novel symmetry properties
- 5: Exotic particles

Partonic structure



- 6: Spin structure of the nucleon
- 7: How to go beyond leading twist and collinear factorization?






- 8: What are the properties of cold nuclear matter?

Summary of the plan


	Near term (Runs 11-13)	Mid-decade (Runs 14-16)	Long term (Runs 17-)
Colliding systems	$p+p, A+A$	$p+p, A+A$	$p+p, p+A, A+A, e+p, e+A$
Upgrades	FGT, FHC, RP, DAQ10K, Trigger	HFT, MTD, Trigger	Forward Instrum, eSTAR, Trigger
(1) Properties of sQGP	$Y, J/\psi \rightarrow ee, m_{ee}, v_2$	$Y, J/\psi \rightarrow \mu\mu, \text{Charm } v_2, R_{CP}, \text{corr}, \Lambda_c/D \text{ ratio}, \mu\text{-atoms}$	$p+A$ comparison
(2) Mechanism of energy loss	Jets, γ -jet, NPE	Charm, Bottom	Jets in CNM, SIDIS, c/b in CNM
(3) QCD critical point	Fluctuations, correlations, particle ratios	Focused study of critical point region	
(4) Novel symmetries	Azimuthal corr, spectral function	$e\text{-}\mu$ corr, $\mu\text{-}\mu$ corr	
(5) Exotic particles	Heavy anti-matter, glueballs		
(6) Proton spin structure	$W A_L, \text{jet and di-jet } A_{LL}, \text{intra-jet corr}, (\Lambda+\bar{\Lambda}) D_{LL}/D_{TT}$		$\bar{\Lambda} D_{LL}/D_{TT}, \text{polarized DIS \& SIDIS}$
(7) QCD beyond collinear fact	Forward A_N		Drell-Yan, F-F corr, polarized SIDIS
(8) Properties of initial state			Charm corr, Drell-Yan, $J/\psi, \text{F-F corr}, \Lambda, \text{DIS, SIDIS}$

Measurements listed when they first become possible
Many will continue in future periods

If Anything is certain, it is Changes will occur

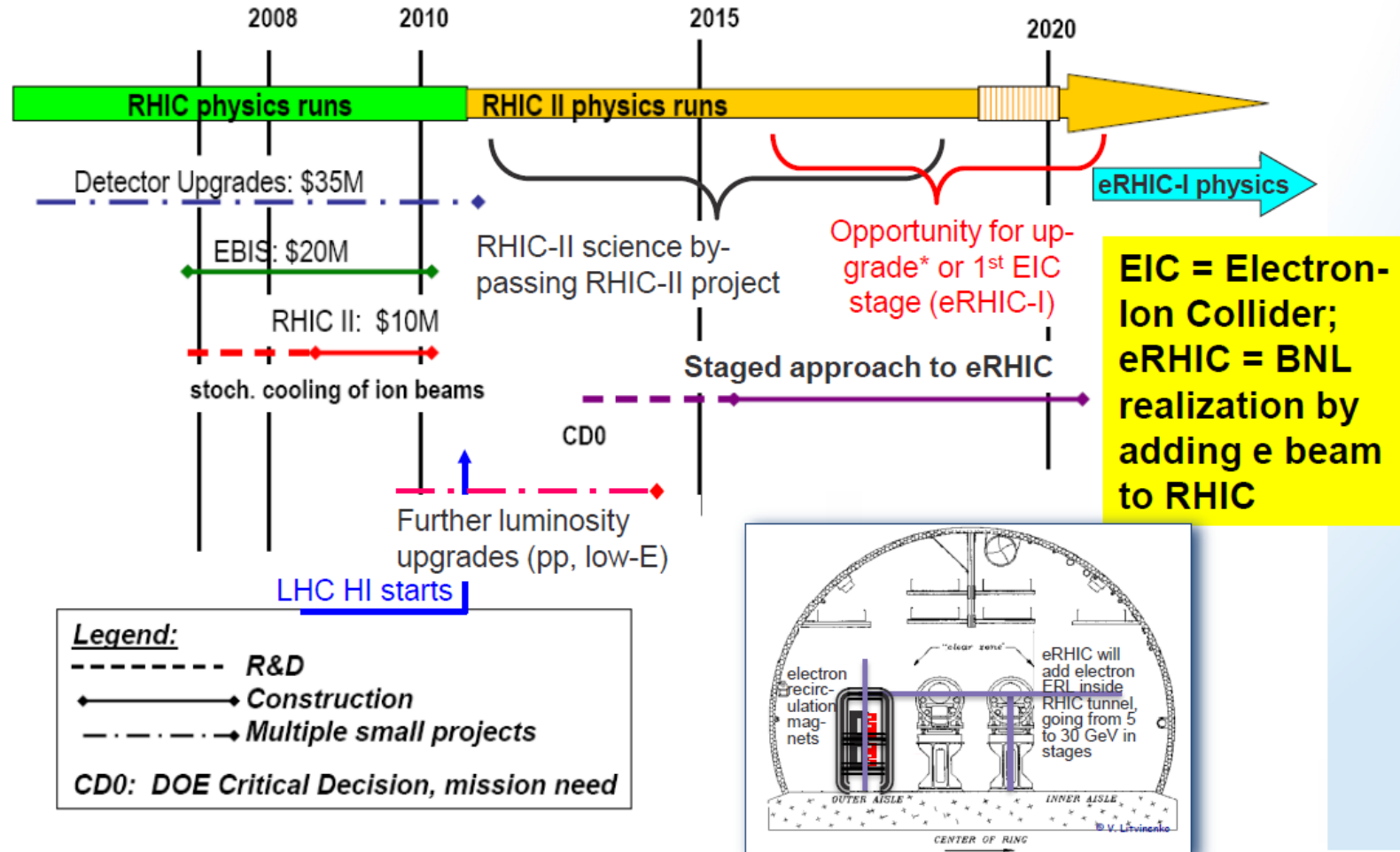
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Colliding systems	$p+p, A+A$	$p+p, A+A$	$p+p, p+A, A+A, e+p, e+A$ 
Upgrades	FGT, FHC, RP, DAQ10K, Trigger	HFT, MTD, Trigger	Forward Instrum, eSTAR, Trigger
(1) Properties of sQGP	$Y, J/\psi \rightarrow ee, m_{ee}, v_2$	$Y, J/\psi \rightarrow \mu\mu, \text{Charm } v_2, R_{CP}, \text{corr}, \Lambda_c/D \text{ ratio}, \mu\text{-atoms}$	$p+A$ comparison
(2) Mechanism of energy loss	Jets, γ -jet, NPE	Charm, Bottom	Jets in CNM, SIDIS, c/b in CNM
(3) QCD critical point	Fluctuations, correlations, particle ratios	Focused study of critical point region 	2019--20
(4) Novel symmetries	Azimuthal corr, spectral function	$e\text{-}\mu$ corr, $\mu\text{-}\mu$ corr	
(5) Exotic particles	Heavy anti-matter, glueballs		
(6) Proton spin structure	$W A_L, \text{jet and di-jet } A_{LL}, \text{intra-jet corr}, (\Lambda+\bar{\Lambda}) D_{LL}/D_{TT}$	Run 15 $p+A$	$\bar{\Lambda} D_{LL}/D_{TT}, \text{polarized DIS \& SIDIS}$
(7) QCD beyond collinear fact	Forward A_N		Drell-Yan, F-F corr, polarized SIDIS
(8) Properties of initial state			Charm corr, Drell-Yan, $J/\psi, F\text{-}F \text{ corr}, \Lambda, \text{DIS, SIDIS}$

Measurements listed when they first become possible
Many will continue in future periods



BNL ALD S. Vigdor talk at 2011 PAC Meeting

A Long Term (Evolving) Strategic View for RHIC



* New PHENIX and STAR Decadal Plans provide options for this period.
Dedicated storage ring for novel charged-particle EDM measurements another option.

BNL ALD B. Mueller's talk at 2015 RHIC/AGS Users Meeting

Proposed run schedule for RHIC

Years	Beam Species and	Science Goals	New Systems
2014	Au+Au at 15 GeV Au+Au at 200 GeV ³ He+Au at 200 GeV	Heavy flavor flow, energy loss, thermalization, etc. Quarkonium studies QCD critical point search	Electron lenses 56 MHz SRF STAR HFT STAR MTD
2015-16	p↑+p↑ at 200 GeV p↑+Au, p↑+Al at 200 GeV High statistics Au+Au Au+Au at 62 GeV ?	Extract $\eta/s(T)$ + constrain initial quantum fluctuations Complete heavy flavor studies Sphaleron tests Parton saturation tests	PHENIX MPC-EX STAR FMS preshower Roman Pots Coherent e-cooling test
2017	p↑+p↑ at 510 GeV	Transverse spin physics Sign change in Sivers function	
2018	No Run		Low energy e-cooling install. STAR iTPC upgrade
2019-20	Au+Au at 5-20 GeV (BES-2)	Search for QCD critical point and onset of deconfinement	Low energy e-cooling
2021-22	Au+Au at 200 GeV p↑+p↑, p↑+Au at 200 GeV	Jet, di-jet, γ -jet probes of parton transport and energy loss mechanism Color screening for different quarkonia Forward spin & initial state physics	sPHENIX Forward upgrades ?
≥ 2023 ?	No Runs		Transition to eRHIC

RHIC Run Plan 2019-25

❖ *Beam Energy Scan II (2019-21):*

- ❖ Low energy ($\sqrt{s_{NN}} = 7.7, 9.1, 11.5, 14.5, 19.6$ GeV) electron cooling to increase luminosity
- ❖ Fixed target runs at (3.0), 3.5, 3.9, 4.5, 5.2 GeV
- ❖ Search for signs of critical phenomena in ϵ

❖ *Forward spin run (2022):* **Fall 2021**

- ❖ 500 GeV p+p (enhanced by forward upgrade)
- ❖ Spin physics measurements complementary to RHIC

❖ *Runs with sPHENIX (2023-25):*

- ❖ Full energy ($\sqrt{s_{NN}} = 200$ GeV) Au+Au, p+p, p+Au
- ❖ Precision measurements of fully resolved jets

2019	28 cryo-weeks with STAR Au+Au at 11.5, 14.5, 19.6 GeV
2020	Au+Au at 3.5, 3.9, 4.5, 5.2, 6.2, 7.7 GeV (FXT)
2021	20 cryo-weeks with STAR Au+Au at 7.7 / 9.1 GeV
2022	16 cryo-weeks with STAR (forward) p+p at 500 GeV
2023	24 cryo-weeks with sPHENIX and STAR Au+Au at 200 GeV
2024	24 cryo-weeks with sPHENIX and STAR p+p and p+Au at 200 GeV
2025	24 cryo-weeks with sPHENIX and STAR Au+Au at 200 GeV

STAR PHYSICS PROGRAM AFTER BES-II

Mid-rapidity $-1.5 < \eta < 1.5$

Forward-rapidity $2.8 < \eta < 4.2$

A+A

Beam:

Full Energy AuAu

Physics Topics:

a deep look into the properties of the QGP:
 γ & $e+e^-$ pairs

- chiral symmetry restoration
- temperature and lifetime of hot, dense medium

Hypertriton Lifetime Measurement

Precision measurements of direct photon yields and v_n

p+p & p+A

Beam:

500 GeV: p+p
200 GeV: p+p and p+A

Physics Topics:

- Improve statistical precision
 - TMD measurements, i.e. Collins, Sivers, ...
 - Access s & Δs through Kaons in jets
- Measurement of GPD E_g through UPC J/ψ
- First access to Wigner functions through di-jets in UPC
- Gluon and quark vacuum fragmentation
- Gluon and quark fragmentation in nuclear medium
- Nuclear dependence of Collins FF

A+A

Beam:

Full Energy AuAu

Physics Topics:

- Temperature dependence of viscosity through flow harmonics up to $\eta \sim 4$
- Longitudinal decorrelation up to $\eta \sim 4$
- Global Lambda Polarization
 - ➔ strong rapidity dependence

p+p & p+A

Beam:

500 GeV: p+p
200 GeV: p+p and p+A

Physics Topics:

- TMD measurements at high x transversity \rightarrow tensor charge
- Improve statistical precision for Sivers through DY
- $\Delta g(x, Q^2)$ at low x through Di-jets
- Gluon PDFs for nuclei
 - R_{pA} for direct photons & DY
- Test of Saturation predictions through di-hadrons, γ -Jets

2021: provides a nice opportunity to run 500 GeV polarized pp
All other data taking in parallel to sPHENIX data taking campaign

Run Plan (STAR)

	2018	2019	2020	2021	2022	2023	2024	2025
Detector configuration	EPD	iTPC/eTOF	Partial Forward	Forward Calorimeter sTGC	FST	NO Detector Upgrade ONLY Operation Driven by sPHENIX		
Operation	Isobar 27GeV FXT	19.6GeV 14.5GeV FXT ?	11.5 9.1 FXT	9.1 7.7	pp500	Au+Au200	pp pA	Au+Au200
weeks	16	24	24	20	16	24	24	24

STAR BUR for BES-II physics data-taking 38 weeks;

Cryoweeks: 68--72 weeks = physics + LEReC + CAD prep

Forward Upgrade Timeline

- 2010-2014 Conceptual Design and Physics cases forward DY, forward Jets, forward photon, forward correlations
- 2015 proposal turned down by BNL
- 2016-2017 strengthen physics cases with new Spin data and LHC/RHIC rapidity correlation results Positive reviews from PAC
- 2018 November BNL Director technical review (positive)

Discussion and summary

- Hardware
 - sTGC components and to-do list
 - Silicon components and to-do list
 - Simulation and to-do list
- Physics cases (Heavy-ions)
 - Global polarization and predictions?
 - System scan: Small systems and measurements?
 - Jet quenching (rapidity dependence)
 - Heavy-flavor, Strangeness and hypertriton?

sTGC

- Module design is still not finalized.
Timeline for finalizing the design and prototype

?BNL

- Prototype tests and performance with different gas

Chi yang

- Electronics and finalize options

BNL, USTC and SDU? (Lijuan)

- Ghost rejection approach (what are the parameters for optimization)

Zhenyu chen

- Funding and manpower
module (estimate cost), electronics (?)

Silicon Strip disks

- Design more or less finalized (end of 2019)
- Further optimization (r segmentation?)

Limitations (shift r if demonstrated necessary from simulations)

- **Mechanic integration**
more regular meetings with STAR support group
- **Prototype status**
sensors (Hamamatsu, NDL) , Two students?

August 2019

- 4th disk option?

Depending on the next couple of iterations of new sensors

- **Funding and Manpower**
mechanic support (NCKU), sensors (NSFC), design/assembly/test (new postdoc)

Tracking algorithm and geometry

- Decide to use the new algorithm

- Finalize the algorithm

Daniel a few weeks

- Optimize sTGC and Silicon approach

- Non-uniform magnetic field

- Manpower
Te-Chuan,

Vorticity and polarization rapidity dependence

- Global, local or circular polarization

Quantify predictions from models

- What do we actually constrain/sensitive to with rapidity measurement

Lambda simulation to be realistic, and some real projection from models

- What required from the forward upgrade?

Small and large System scan

- Longitudinal pt differential Measurement:
Rapidity (de)correlation (r_n) , ridge

Reduce non-flow in small systems

- Disentangle initial vs final state effects?
- Together with mid-rapidity measurement?
Is there an identifiable case?
Forward measurement helps understand midrapidity
- To-do list
Jiangyong and Prithwish

Jet quenching

- Rapidity dependence:
bulk profile change;
spectral shape and q/g content change
jet shape

- What is the message?

Effectively jet quenching in HIGH MU_B

- To-do list
Nihar Sahoo

HF, Strangeness and hypertriton

- Gluon PDF? J/psi rapidity

- Chemical content
Lambda and Ks?

How about multiple strangeness baryons?

- V1 SLOPES
- Hypernuclei
similar to reconstruct Lambda,
use EPD to identify $z=+2$