Strangeness Probes of QCD Matter from RHIC Beam Energy Scan

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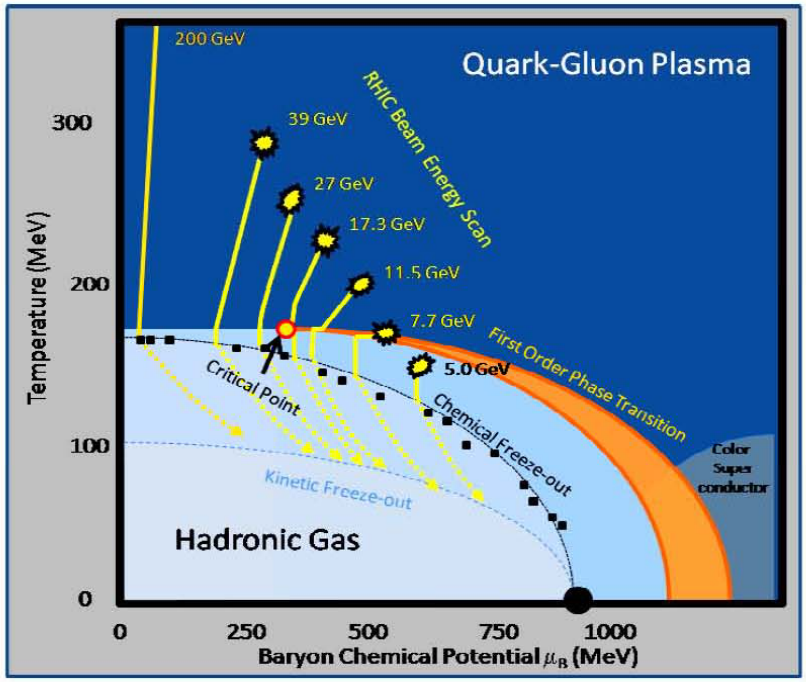
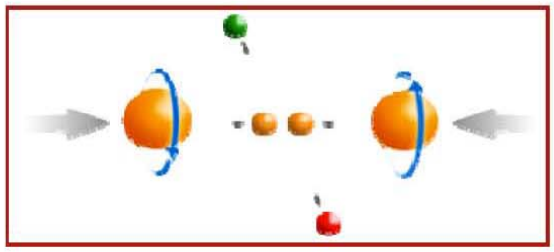
Very Exciting Scientific Program and Detector Upgrades for the coming decade

Hot QCD Matter

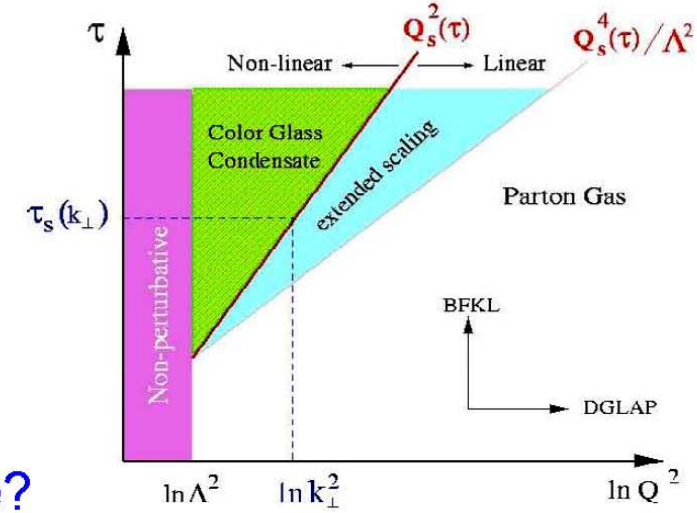


1: Properties of the sQGP
2: Mechanism of energy loss:
weak or strong coupling?
3: Is there a critical point, and if so, where?
4: Novel symmetry properties
5: Exotic particles

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?

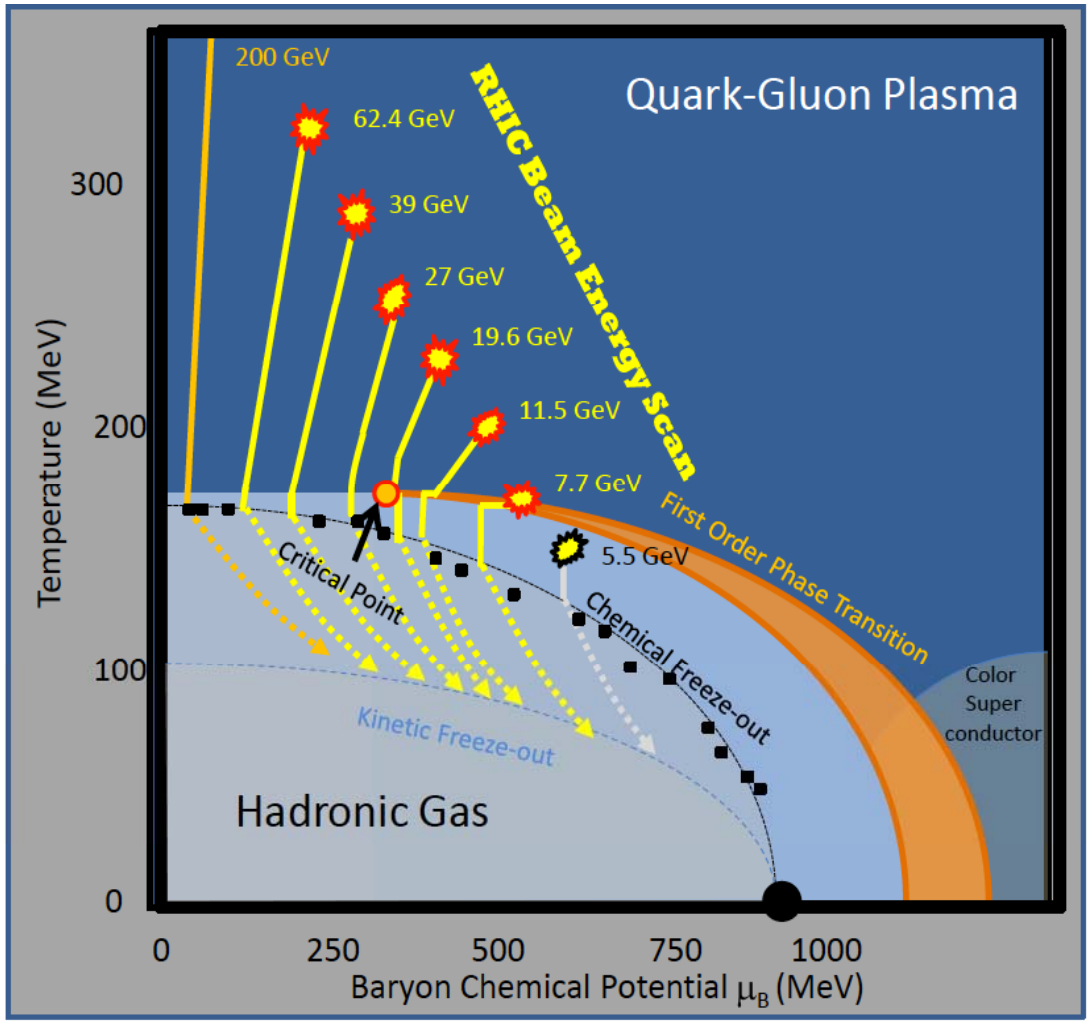
Outline

RHIC Beam Energy Scan Program

Strange Baryon, Coalescence and Parton distribution from Bulk Matter

Test Thermal Statistical Model

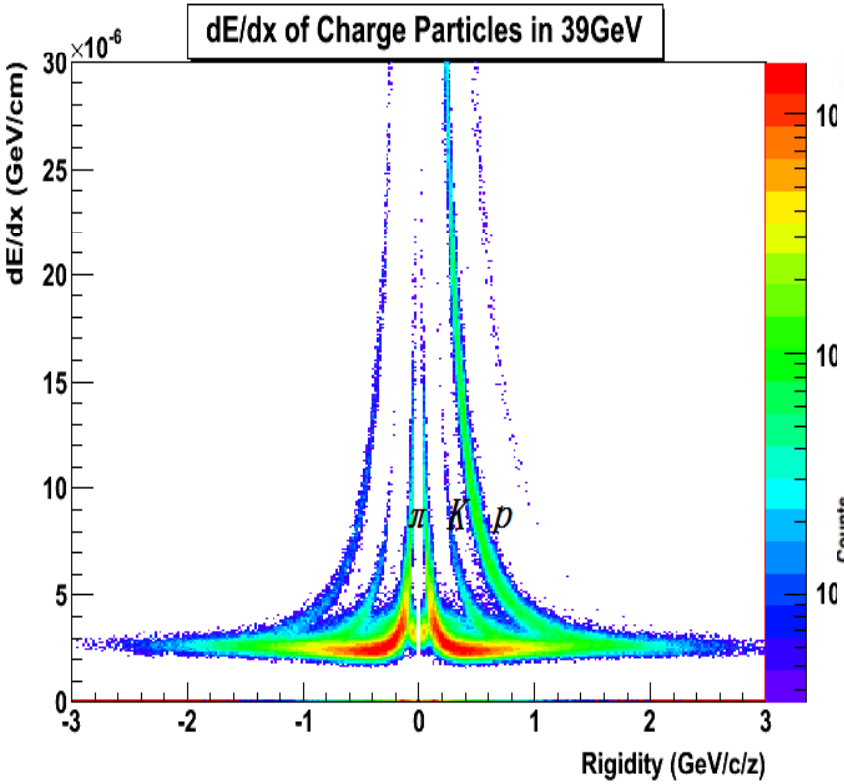
QCD Phase Diagram and RHIC BES-I

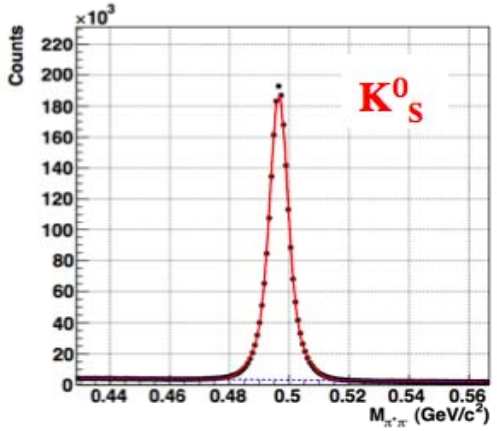


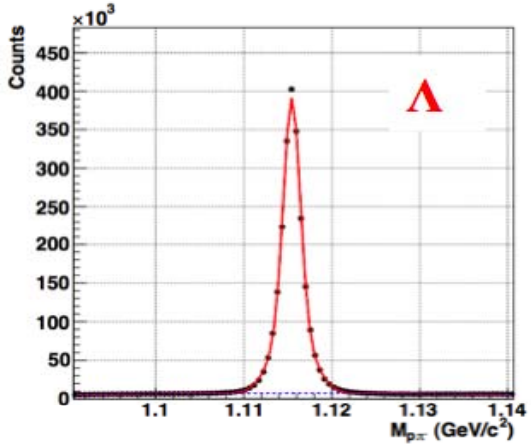
Year	En (GeV)	# Event (10^6)
2010	39	130
2010	11.5	12
2010	7.7	5
2011	27	70
2011	19.6	36
2014	15	

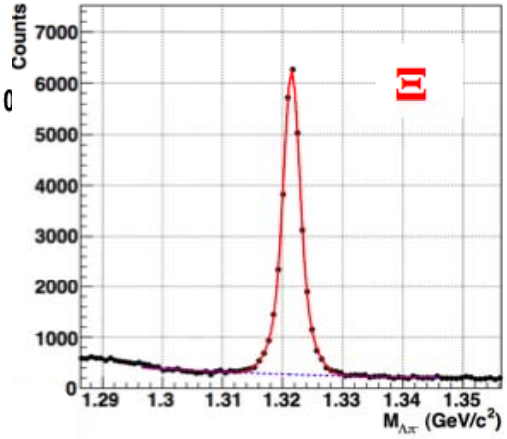
RHIC can deliver low energy beams
STAR has almost uniform acceptance independent of beam energy
Luminosity/Data-taking efficiency !!

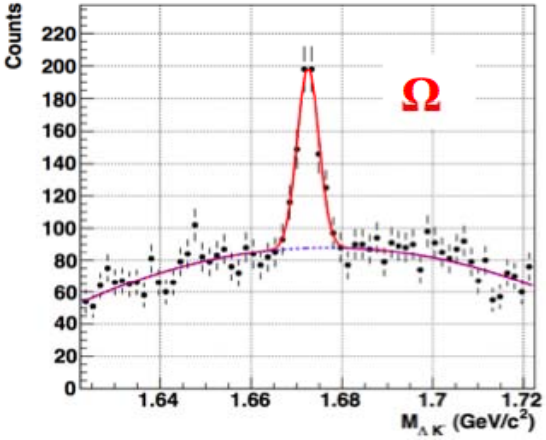
Signal Reconstruction



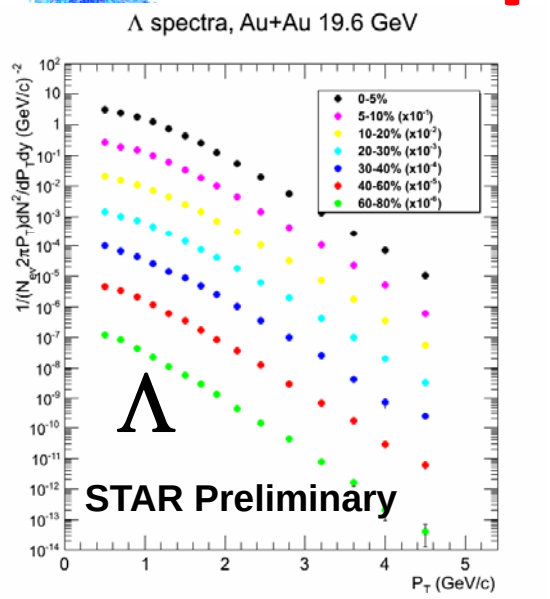


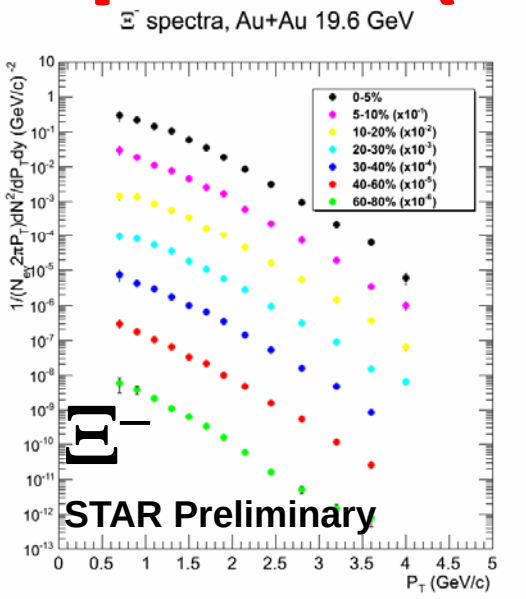


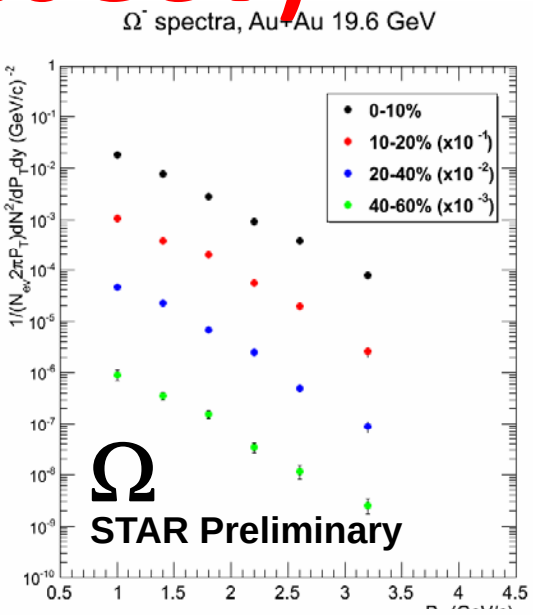


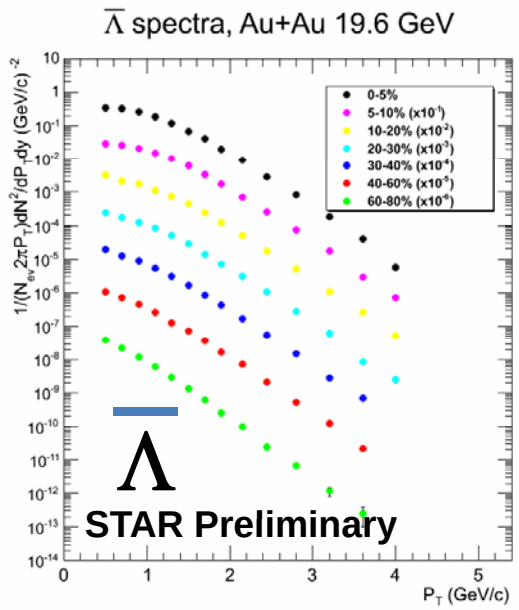


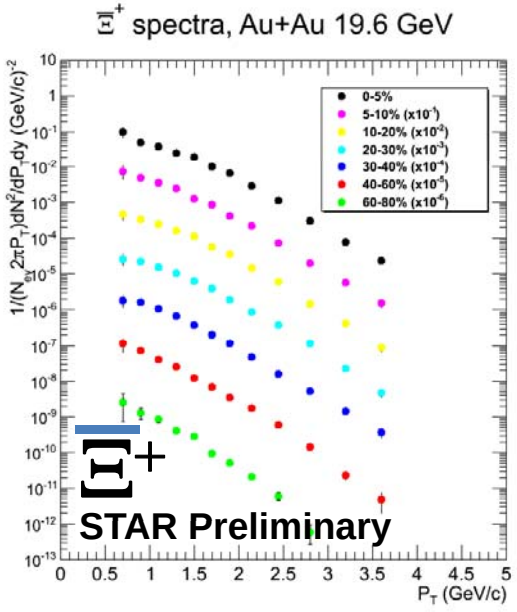
p_T Spectra (19.6GeV)

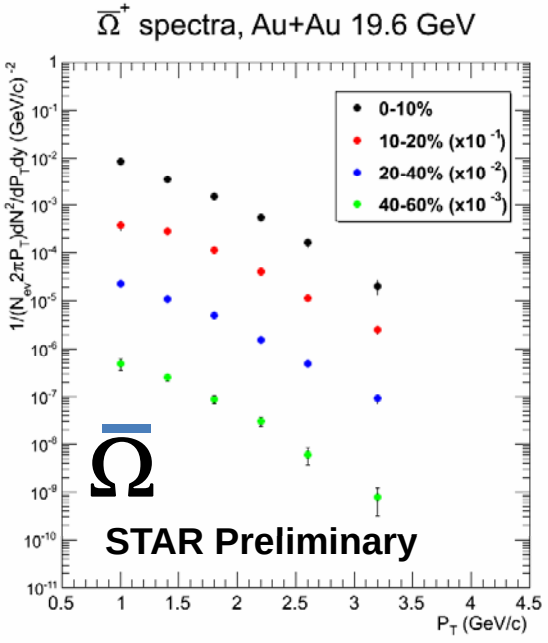




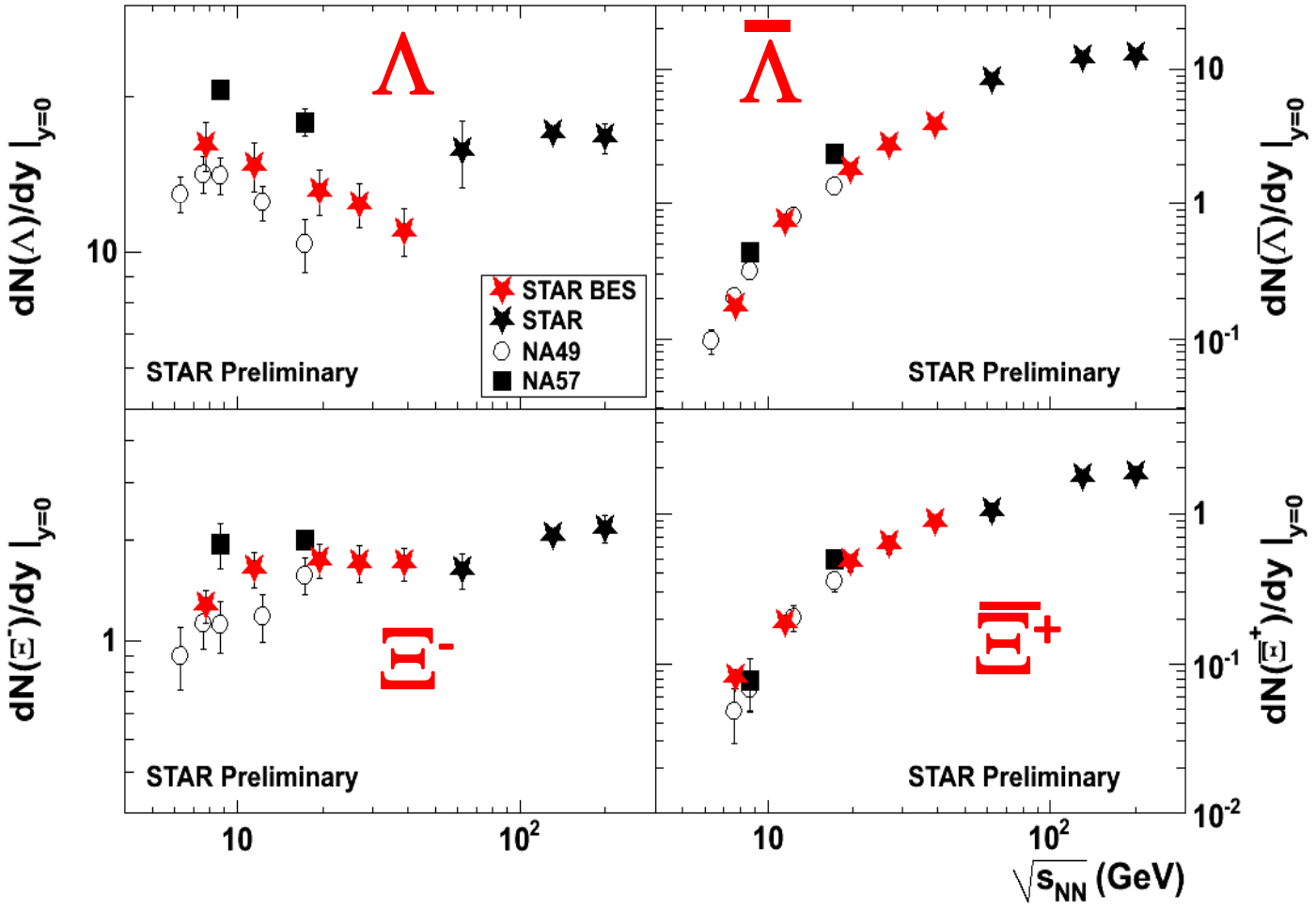








Mid-Rapidity Hyperon Yield



Mechanism:
Pair Production
Associated Prod.

-- quark or hadron level

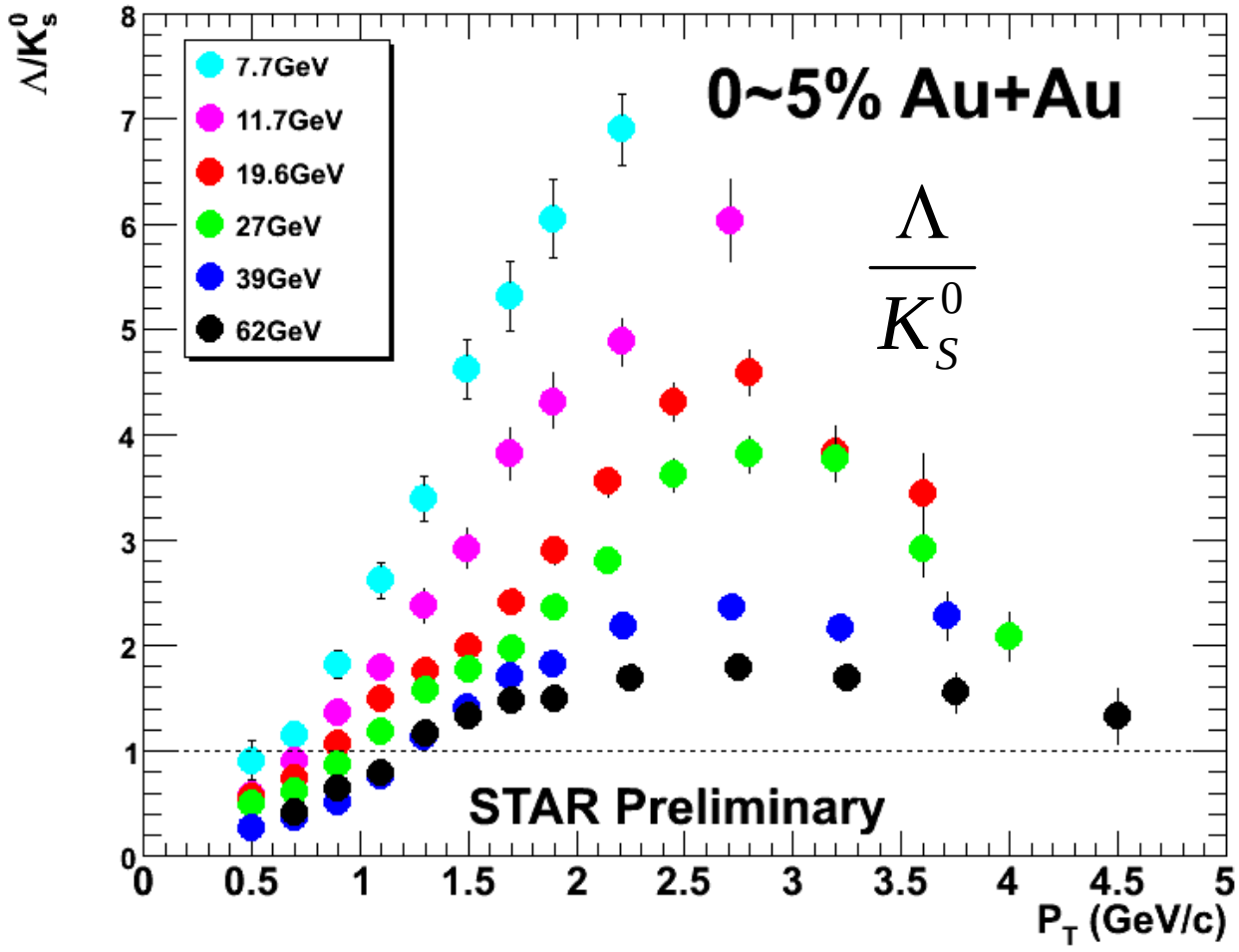
-- difference in hyperon vs. anti-hyperons

-- sensitive to chemical potential

Coalescence and Cluster Formation

Increased Hyperon over Ks ratios

The formation probabilities of baryons and mesons depend on the environment – local parton density



B/m ratios
-- measure of local parton density at hadronization !

Au+Au at 7.7 GeV
-- higher net baryon density !

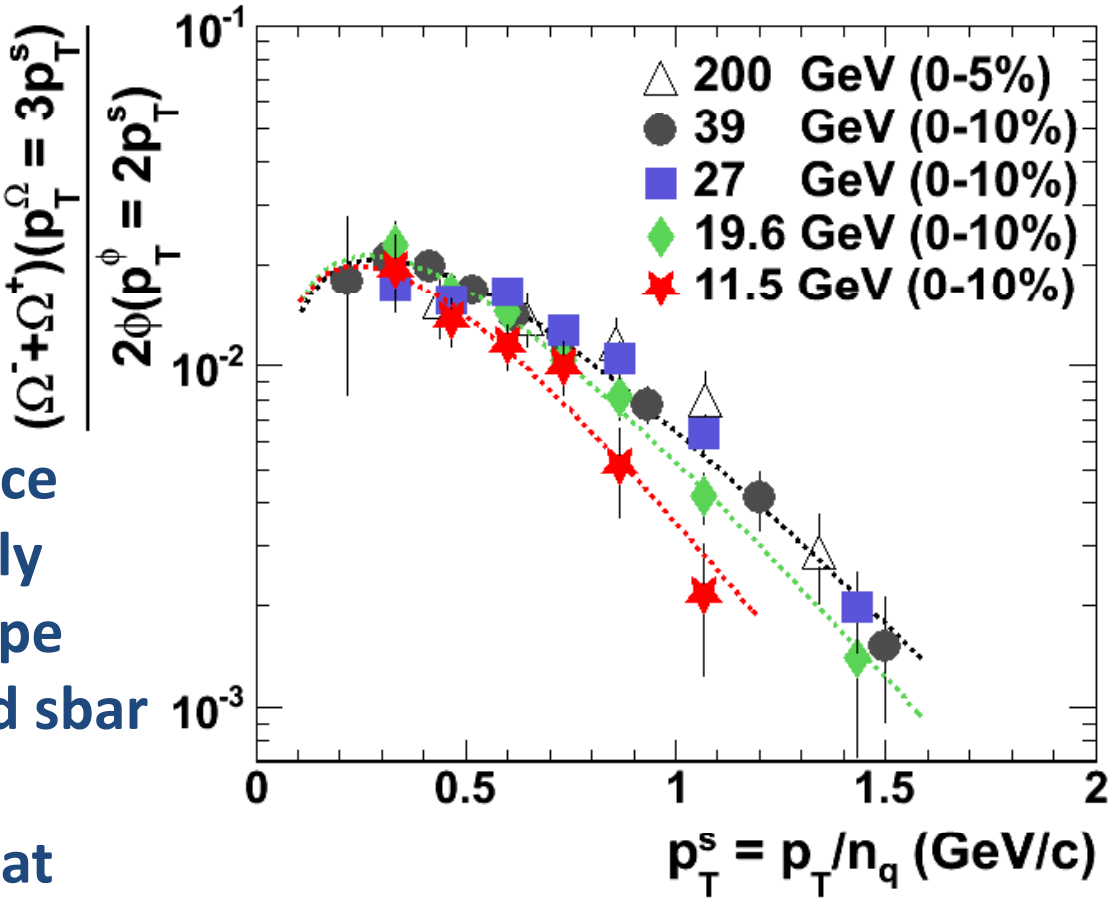
In a broad pT region [1-4] GeV/c, much more hyperons than mesons produced !!
-- Coalescence

Strange quark analysis from Ω and ϕ using Coalescence Framework

Ω(sss) and ϕ(s$\bar{s}$) formed at chemical freezeout from coalescence of 3 s quarks and s-sbar pairs.

Assuming sudden coalescence of s quarks of approximately equal pT and the same shape of pT distributions for s and sbar quarks

The s quark pT distribution at freeze-out ~ $\Omega(3p_T)/\phi(2p_T)$



IS there a difference in partonic dynamics between 11 and 20 GeV?

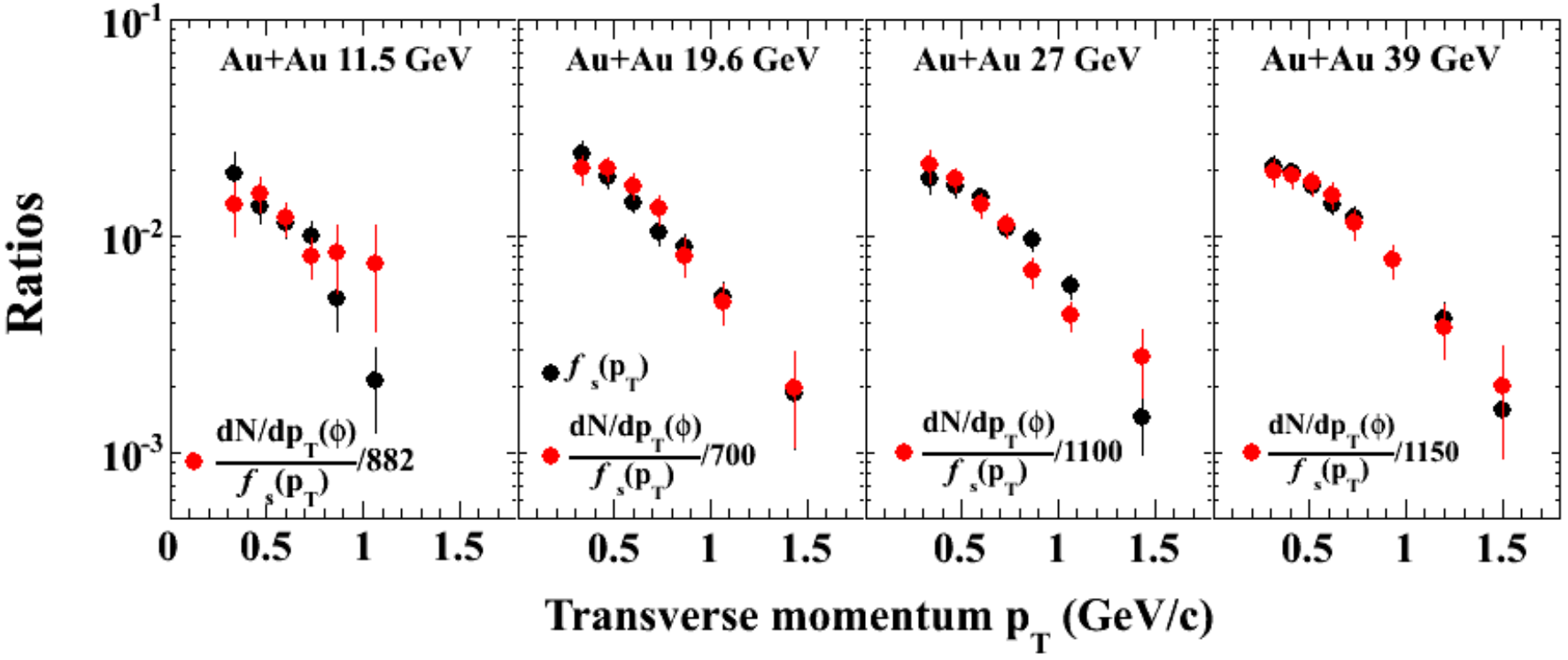
NEED more statistics (BES II) and a 15 GeV run !!

Coalescence Picture !

Independent Empirical Check on Coalescence –

if $s(p_T) \sim \Omega(3p_T)/\phi(2p_T)$, then $\phi(2p_T)/s(p_T)$ is also $s(p_T)$

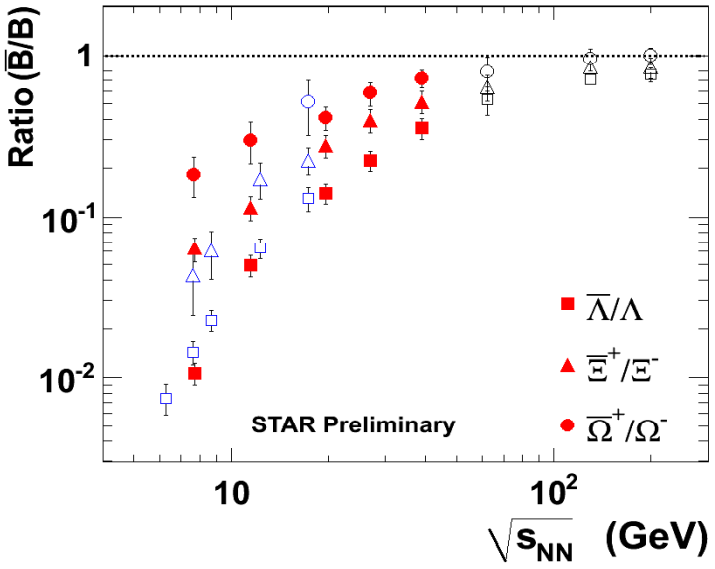
are these functions of similar shape?



NEED More Data at 11.5 GeV !!

Test Thermal Statistical Model

$$n_i = \frac{g_i}{(2\pi^2)} \gamma_S^{|S_i|} m_i^2 T K_2(m_i/T) \exp(\mu_i/T)$$



Central Au+Au (Pb+Pb) Collisions

Solid red: STAR BES;
Open black: STAR published;
Open blue: NA49

Do these ratios satisfy Thermal Model?
Why these ratios? Feeddown corrected !

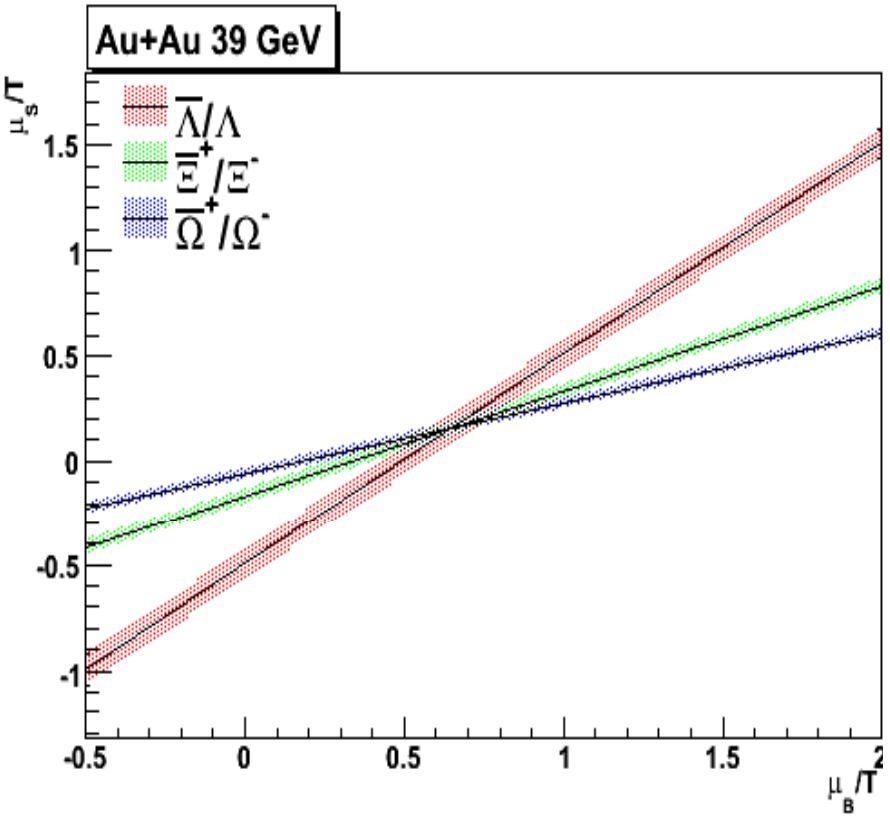
$$\frac{\bar{\Lambda}}{\Lambda} = \exp(-\frac{2\mu_B}{T} + \frac{2\mu_S}{T}) \qquad \ln(\frac{\bar{\Lambda}}{\Lambda}) = -\frac{2\mu_B}{T} + \frac{2\mu_S}{T}$$

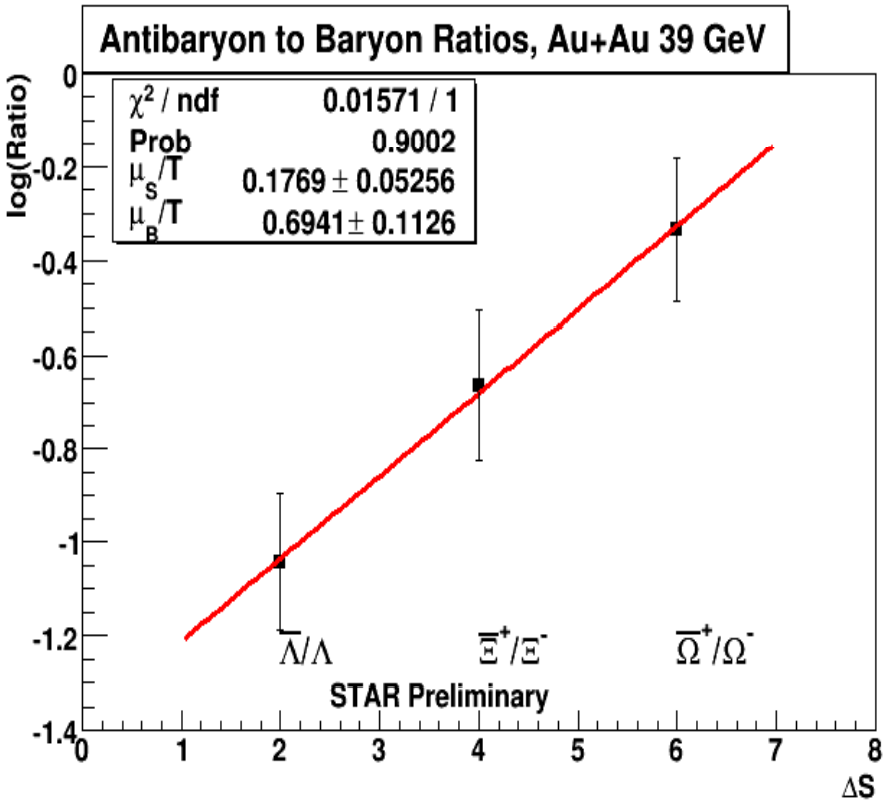
$$\frac{\bar{\Xi}^+}{\Xi^-} = \exp(-\frac{2\mu_B}{T} + \frac{4\mu_S}{T}) \qquad \ln(\frac{\bar{\Xi}^+}{\Xi^-}) = -\frac{2\mu_B}{T} + \frac{4\mu_S}{T}$$

$$\frac{\bar{\Omega}^+}{\Omega^-} = \exp(-\frac{2\mu_B}{T} + \frac{6\mu_S}{T}) \qquad \ln(\frac{\bar{\Omega}^+}{\Omega^-}) = -\frac{2\mu_B}{T} + \frac{6\mu_S}{T}$$

Anti-hyperon to Hyperon Ratios

$$\ln(Ratio) = -\frac{2\mu_B}{T} + \frac{\mu_S}{T} \times \Delta S$$





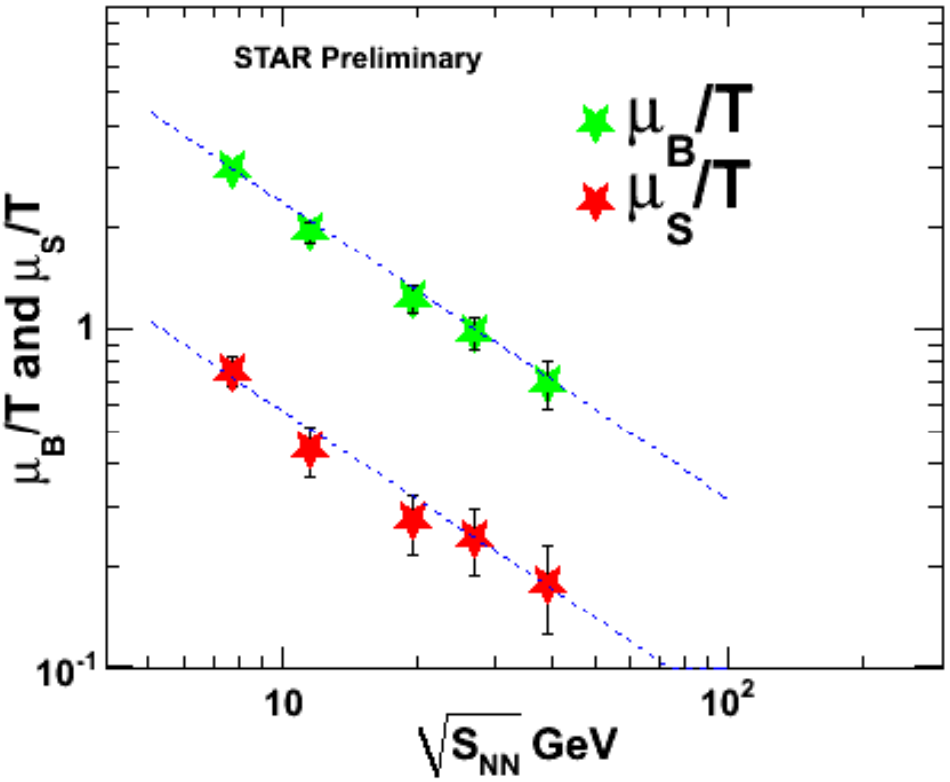
Anti-hyperon to hyperon ratios

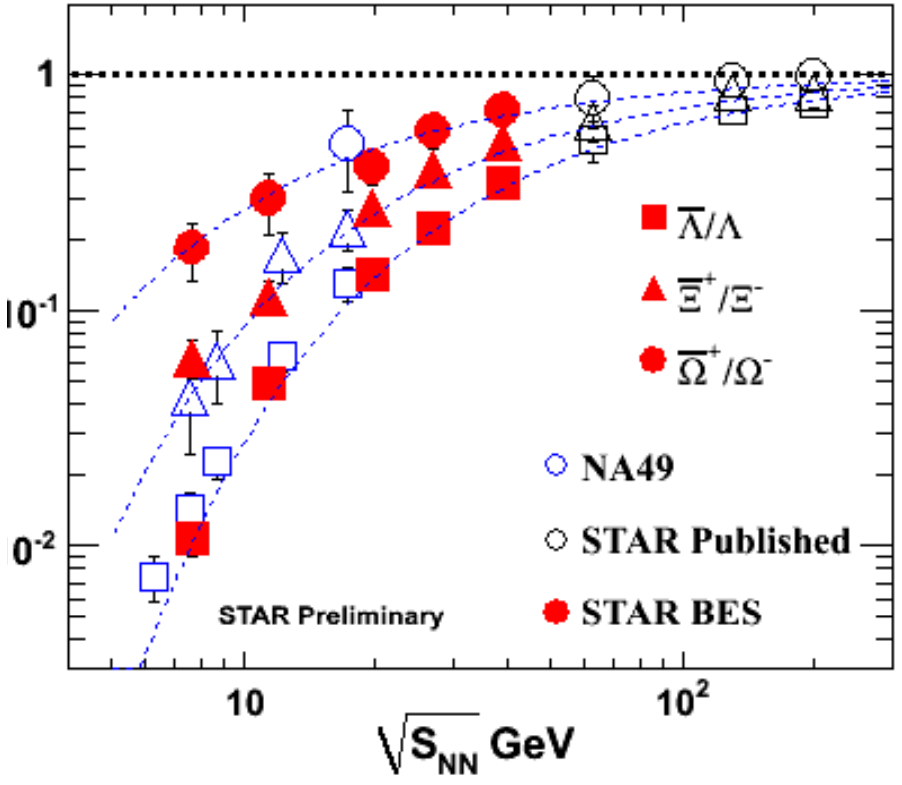
-- remarkably consistent with thermal model!

Beam Energy Dependence

Beam Energy Dependence of μ_B/T and μ_S/T can be described by a parameterization from

F.Becattini et al. Phys Rev C 73, 044905 (2006)



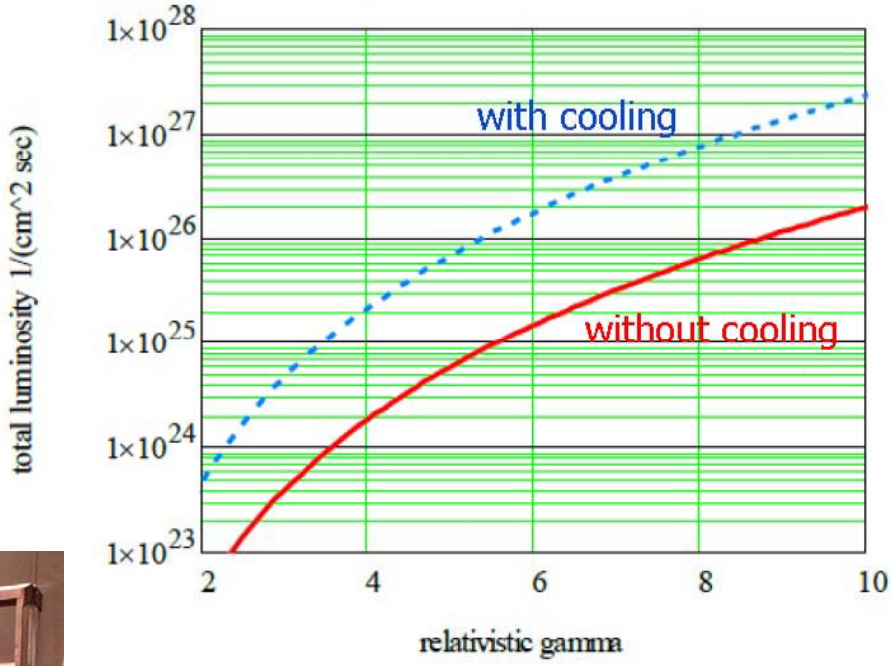


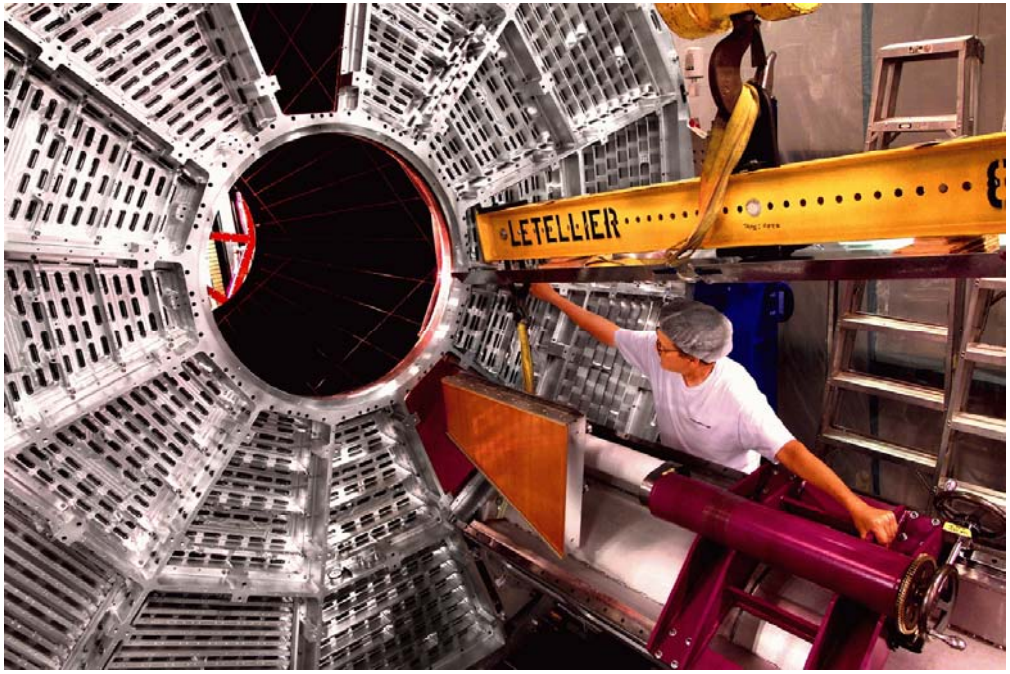
Thermal Statistical Model Works for Hyperons !

Need BESII for precision test !

Road to Beam Energy Scan II

1) Need electron cooling to be more efficient !





2) STAR TPC Inner Sector readout upgrade
-- enhance tracking and PID in η 1-1.7 region

BES II Starting 2018+

RHIC – a Dedicated QCD Facility

QCD – Fundamental Corner Stone of the Standard Model !!

-Dynamics of QCD in bulk matter, vacuum structure and hadrons?

Condensed Matter Physics with Underlying QCD Interactions !

We are beyond the QGP discovery phase already !

LHC -- Energy/Temperature Frontier

RHIC – New Horizons in QCD Phase Structure, Vacuum Excitation, Initial State Color Charge Dynamics, Hadron Structure and Exotics

RHIC Beam Energy Scan Program provides unique experimental opportunity to study the transition in dynamics from parton degree of freedom to hadronic matter and to search for possible critical point in QCD phase diagram ! BES II 2018+