What can we learn from RHIC proton multiplicity distributions on QCD phase diagram ?

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Grand-Canonical Partition Function

⇔

Canonical Partition Function

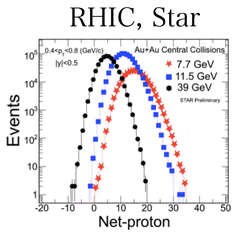
$$Z(\mu,T) = \mathrm{Tr}\, e^{-(H-\mu\hat{N})/T}$$
$$= \sum_n \langle n| e^{-(H-\mu\hat{N})/T} |n\rangle$$

We assume $[H,\hat{N}]=0$

$$= \sum_n \langle n| e^{-H/T} |n\rangle\, e^{\mu n/T}$$
$$= \sum_n \langle n| e^{-H/T} |n\rangle\, e^{\mu n/T}$$
$$= \sum_n Z_n(T)\xi^n, \quad (\xi = e^{\mu/T})$$

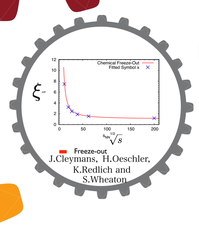
$$Z(\xi,T) = \sum_n Z_n(T)\,\xi^n$$

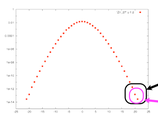
RHIC, Star



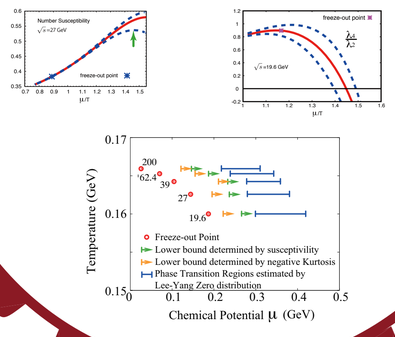
Net-Proton Multiplicity

Partition Function is Sum of the Probability.
If I know ξ, then I have Zn



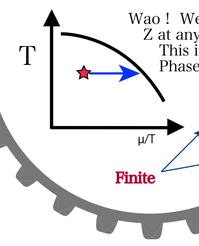


What happens
if we increase these points 15%
if we drop these points



$$Z(\xi,T) = \sum_n Z_n(T)\,\xi^n$$

Now we have Zn of RHIC data (sqrt(s)=9.6, 27, 39, 62.4, 200 GeV)

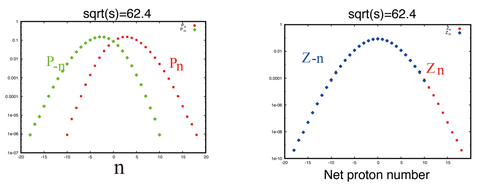


Wao ! We can calculate Z at any density !
This includes all QCD Phase information !

Not true

$$Z_n = P_n/\xi^n$$
$$P_n = Z_n\xi^n$$

ξ :Parameter

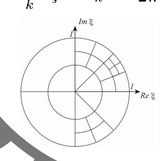


$$Z_{+n} = Z_{-n}$$

Canonical Partition Functions

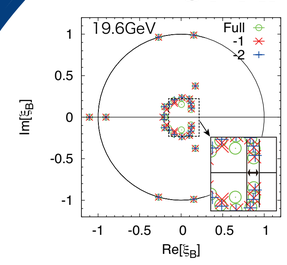
Lee-Yang Zeros

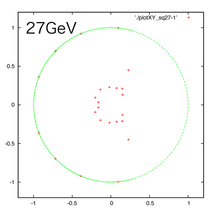
$$Z(\alpha_k) = 0$$
$$Z(\xi,T) \propto \prod_k (\xi - \alpha_k) \equiv f(\xi)$$
$$\frac{f'}{f} = \sum_k \frac{1}{\xi - \alpha_k} \qquad \frac{1}{2\pi}\oint_C \frac{f'(\xi)}{f(\xi)} d\xi = \text{No. of Zeros in C}$$

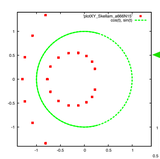


cut Baum-Kuchen

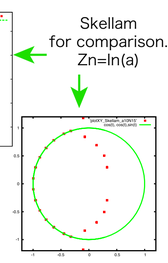
Lee-Yang Zeros of RHIC data

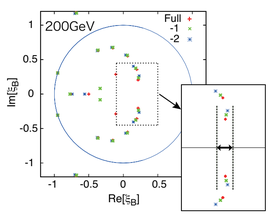






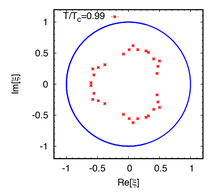
Skellam for comparison. Zn=ln(a)

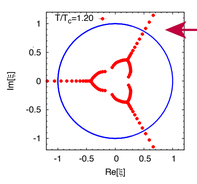




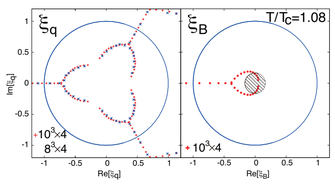
I see why Lee-Yang zeros appear on the unit circle.

Lee-Yang Zeros of lattice QCD





Roberge-Weise Phase Transition !



arXiv:1305.0760
``Probing QCD Phase Structure by Baryon Multiplicity Distribution''
Atsushi Nakamura and Keitaro Nagata