# Hot-dense Lattice QCD within USQCD: perspective & directions

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# USQCD's hot-dense community

HotQCD collaboration

US-based:
~10 institutions,
20+ members

BNL LGT (NP)

Karsch
Mukherjee
Ohno
Petreczky
Sharma
Steinbrecher

international partners

Bielefeld,
Wuhan,
Tsukuba,
Bangalore,
...

# scientific & experimental drivers

immediate & urgent:

RHIC Beam Energy Scan (BES) II 2019–2020

phases & properties of baryon-rich QGP

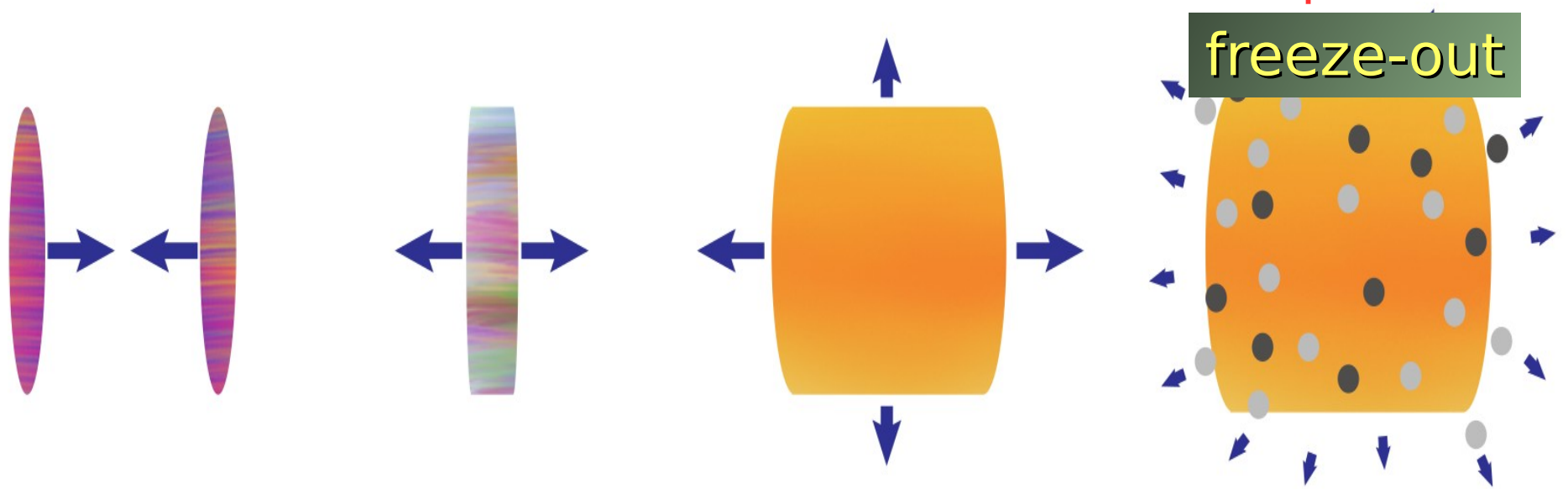
& beyond ...

sPHENIX & ALICE updrades 2021–

heavy flavor probes of QGP

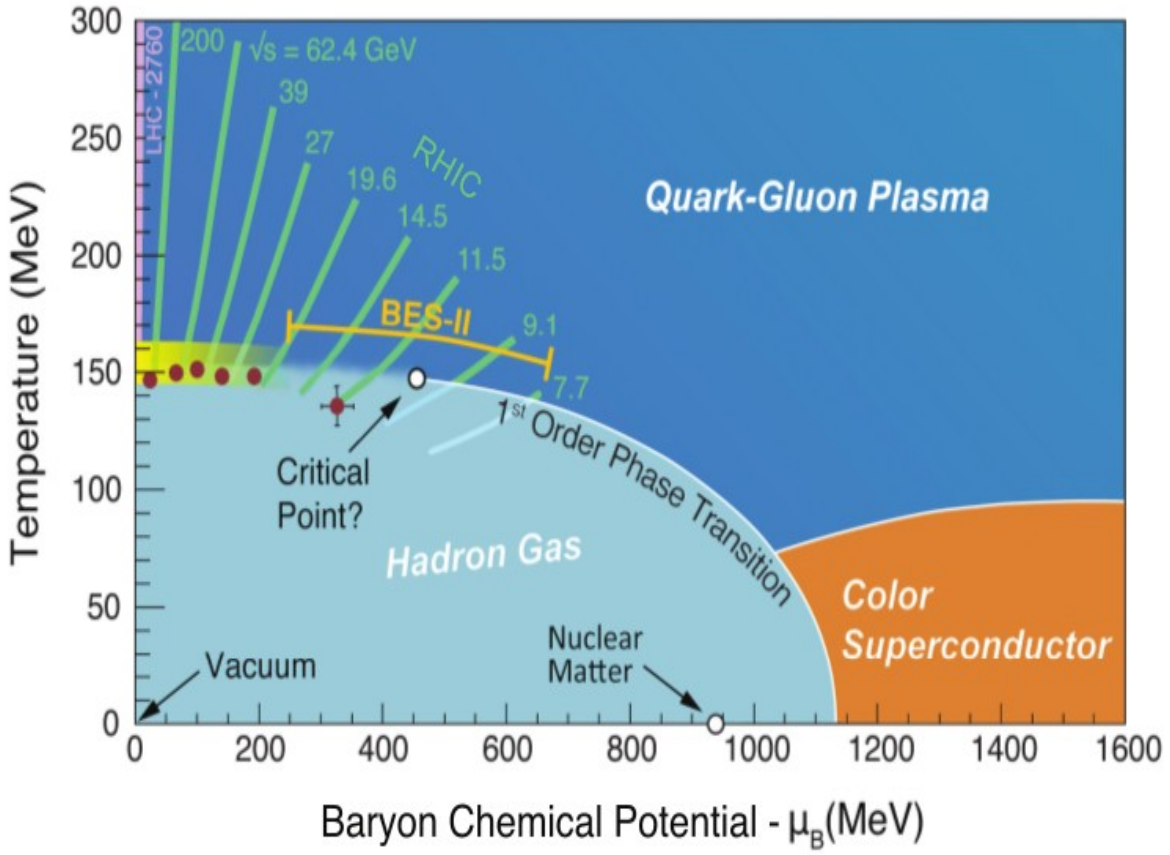
# RHIC Beam Energy Scan

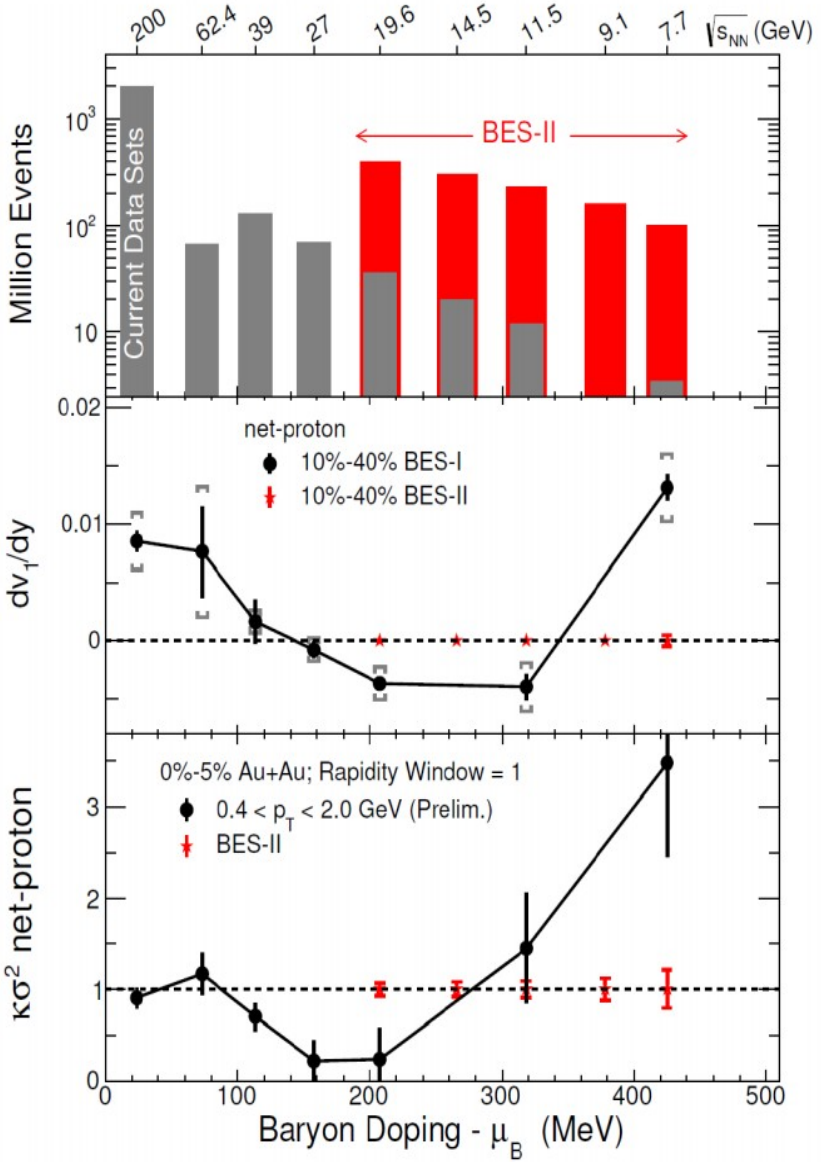
hadrons seen
in experiments



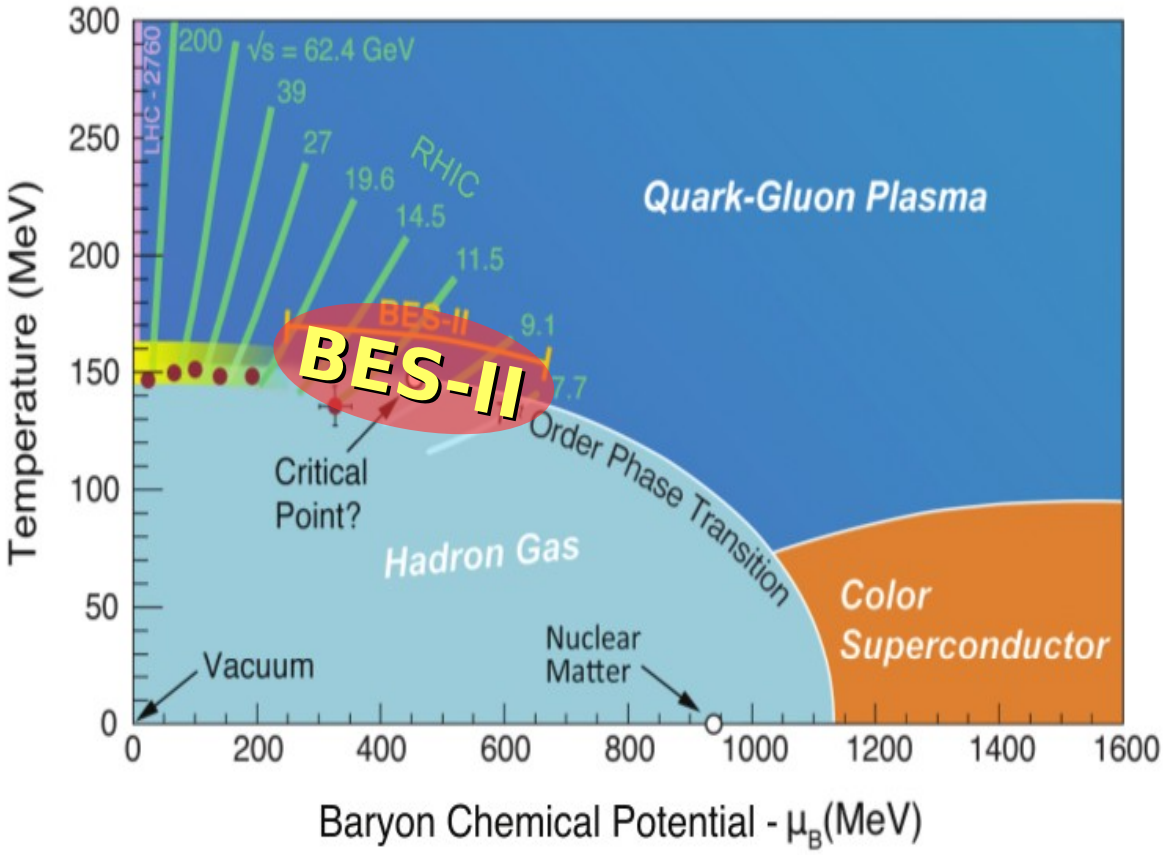

$T^f$: freeze-out temperature

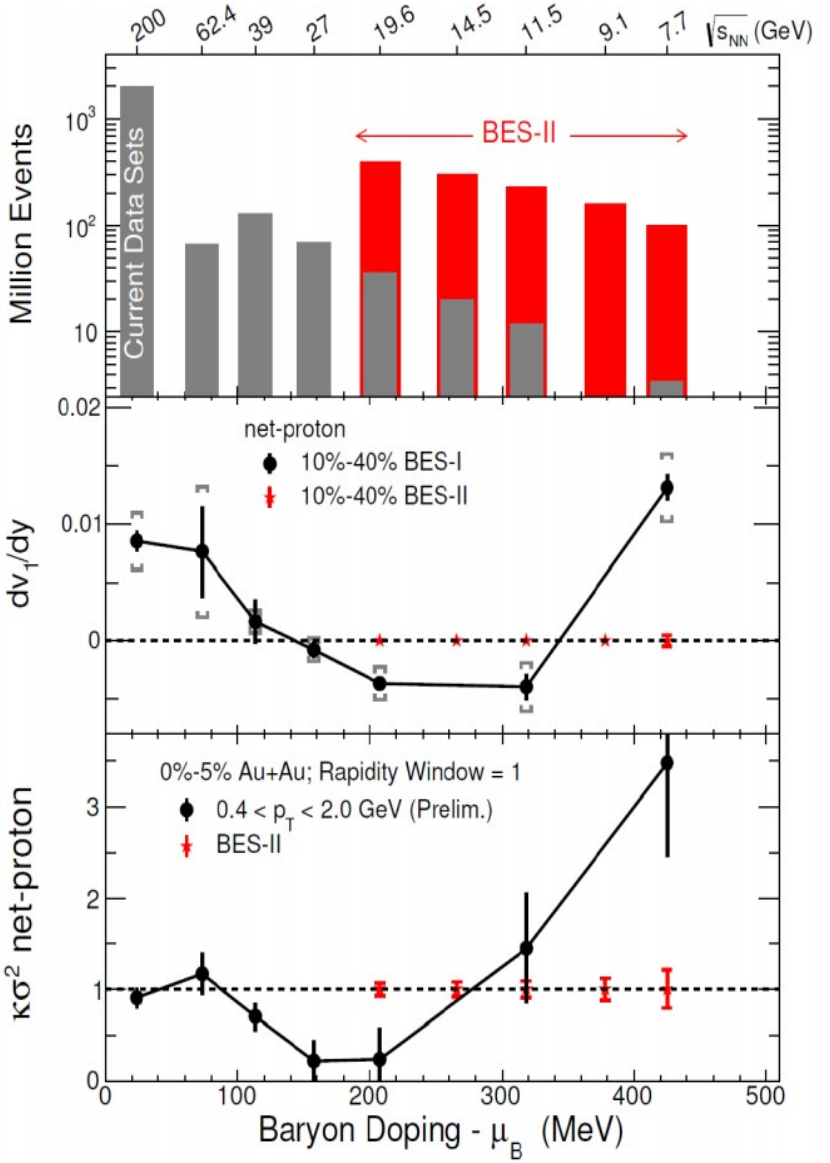
$\mu_B^f$ : freeze-out baryon chemical potential


Temperature (MeV)
Baryon Chemical Potential - $\mu_B$(MeV)
LHC - 2760
200
√s = 62.4 GeV
39
27
19.6
14.5
11.5
9.1
7.7
RHIC
BES-II
Quark-Gluon Plasma
1st Order Phase Transition
Critical Point?
Hadron Gas
Color Superconductor
Vacuum
Nuclear Matter


200
62.4
39
27
19.6
14.5
11.5
9.1
7.7
$\sqrt{s_{NN}}$ (GeV)
Million Events
Current Data Sets
BES-II
net-proton
10%-40% BES-I
10%-40% BES-II
$dv_1/dy$
0%-5% Au+Au; Rapidity Window = 1
0.4 < $p_T$ < 2.0 GeV (Prelim.)
BES-II
$\kappa\sigma^2$ net-proton
Baryon Doping - $\mu_B$ (MeV)

# BES II: $\mu_B^f/T^f \approx 1.3-3$



# hot-dense LQCD for BES-II

Topical Collaboration
in nuclear theory

integral part of a larger
US-based nuclear theory effort:

13 institutions, 17 PIs


lead by: BNL LGT (NP)

project director: SM

funded by:
DOE, Office Of Nuclear Physics
2016-2020

bulk thermodynamics @
baryon chemical potential > 0

Taylor expansion method

- equation of state
- QCD transition temperature
- ...

presently the only viable method for physical quark masses, close to thermodynamic & continuum limit

BNL + international collaborators

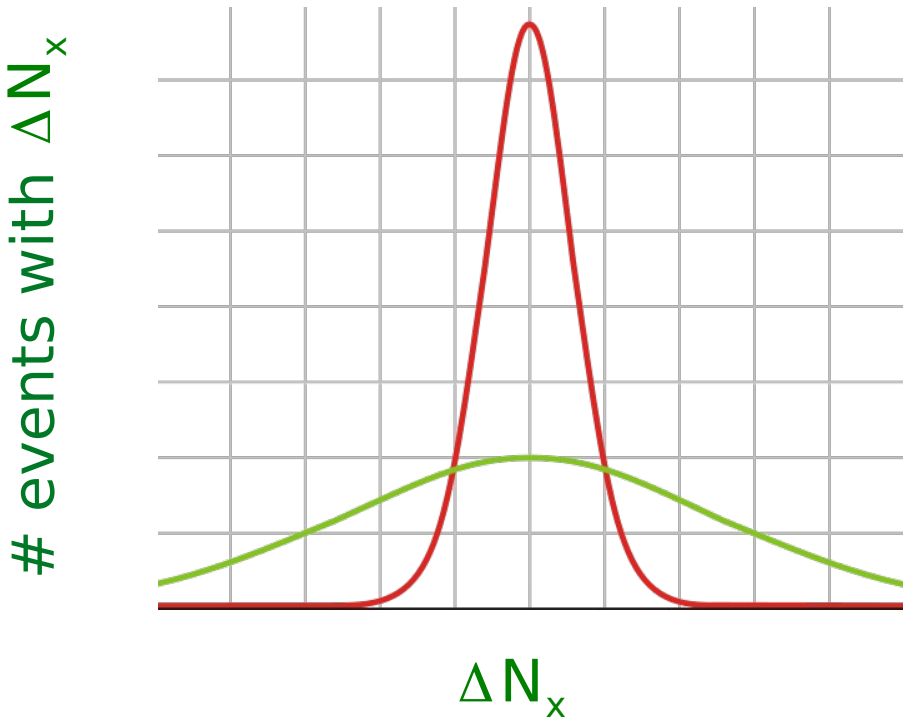
this year: proposal by Sharma

experimentally measurable net-fluctuations

HotQCD collaboration

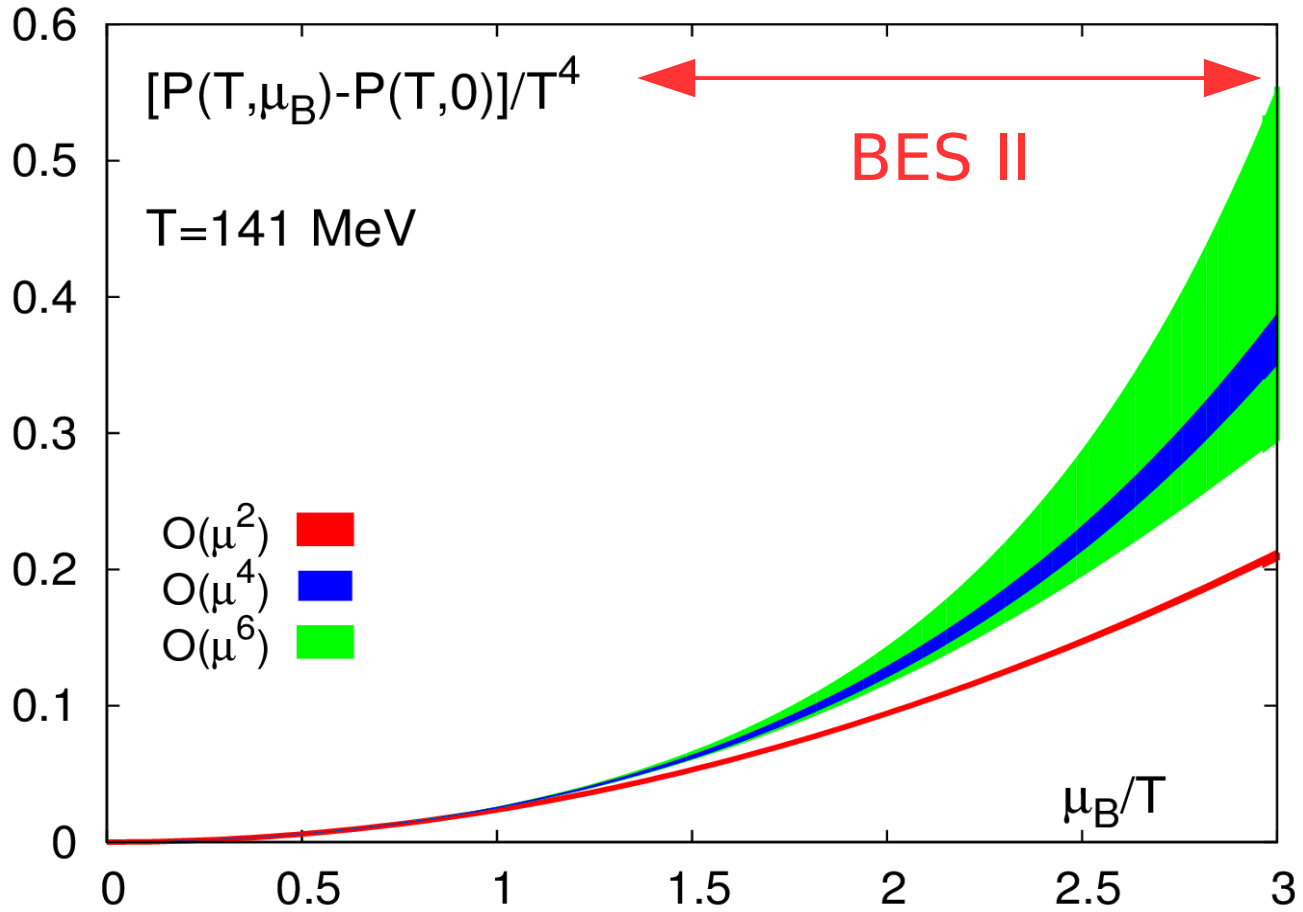
this year: no INCITE time, no proposal

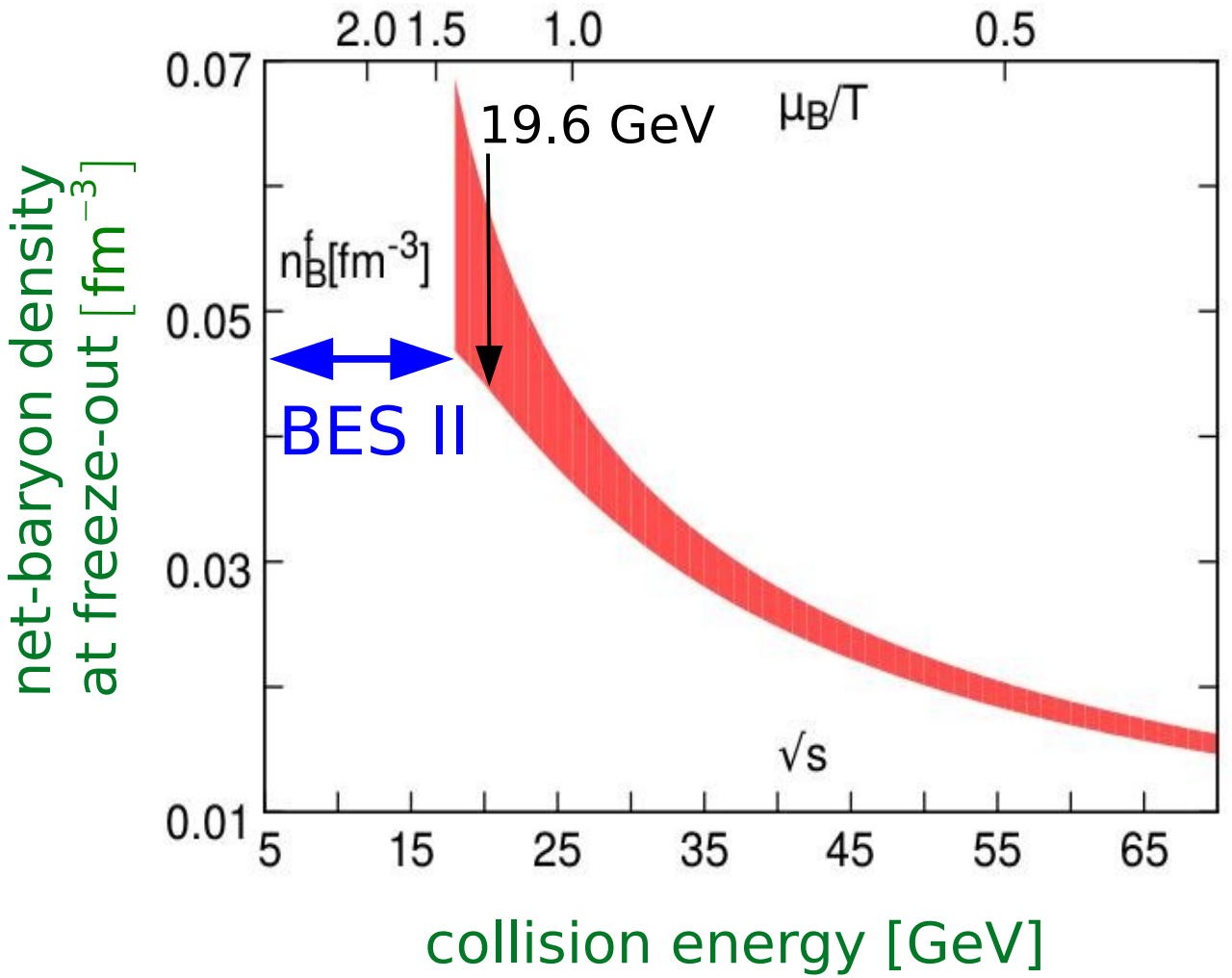
Taylor expansion method →
cumulants of net-charge distribution

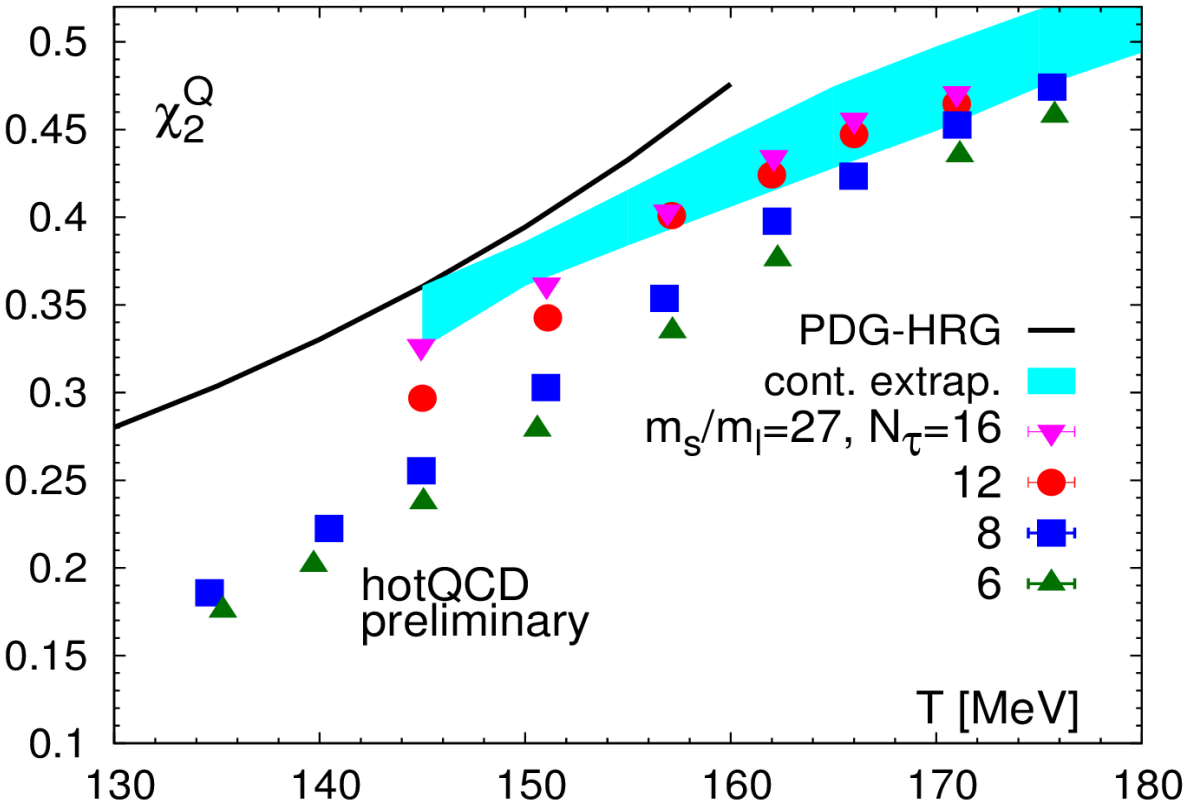



baryon:
narrow, super-high statistics

electric charge:
dominated by pions,
control taste-splitting,
continuum limit essential


[P(T,μB)-P(T,0)]/T4
T=141 MeV
BES II
O(μ2)
O(μ4)
O(μ6)
μB/T
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.5
1
1.5
2
2.5
3


2.0 1.5
1.0
0.5
0.07
0.05
0.03
0.01
19.6 GeV
μB/T
nBf[fm-3]
BES II
√s
5
15
25
35
45
55
65
net-baryon density
at freeze-out [fm−3]
collision energy [GeV]


0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
130
140
150
160
170
180
$\chi_2^Q$
PDG-HRG
cont. extrap.
$m_s/m_l$=27, $N_\tau$=16
12
8
6
hotQCD
preliminary
T [MeV]

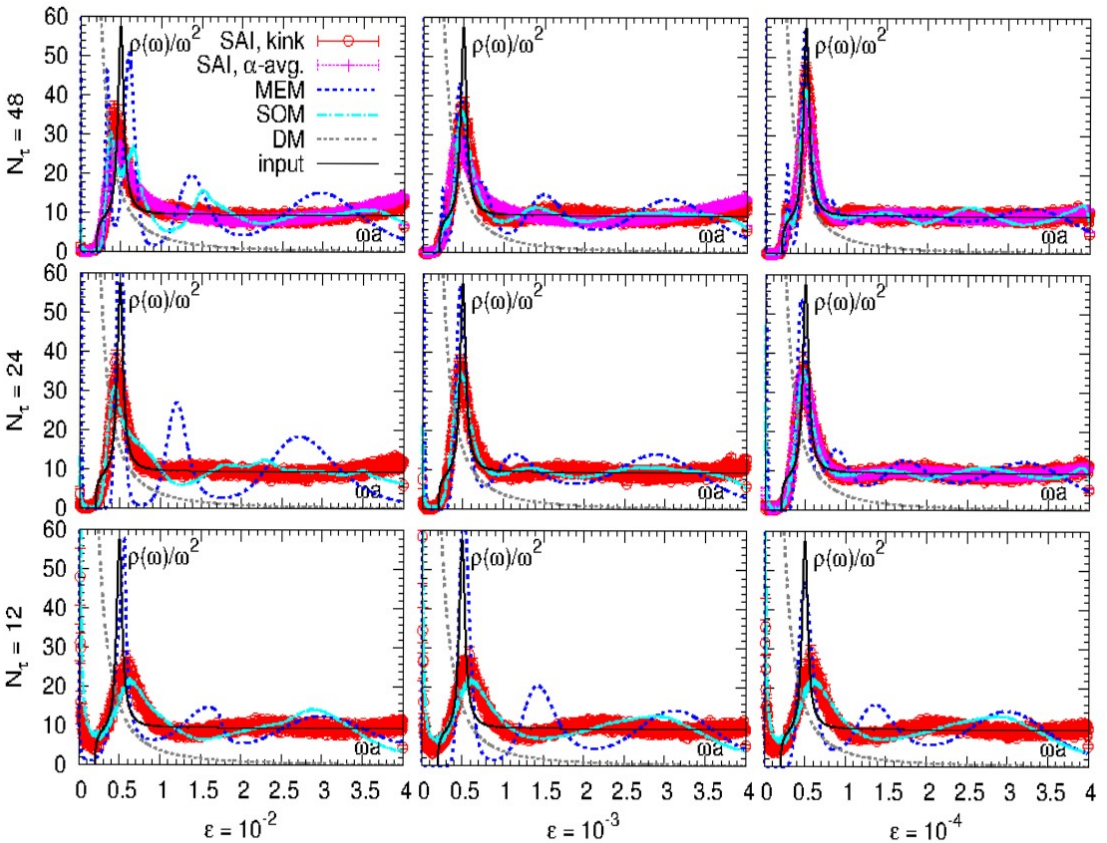
# heavy flavor probes with hot LQCD

sharpening tools

new methods for spectral function reconstructions

stochastic optimization, stochastic analysis inference

Ohno, Mukherjee et. al.: arXiv:1510.02901




this year: Petreczky, bottomonia in QGP, 22M J/Psi core-hr