Measuring QGP temperature with thermal dielectrons at STAR

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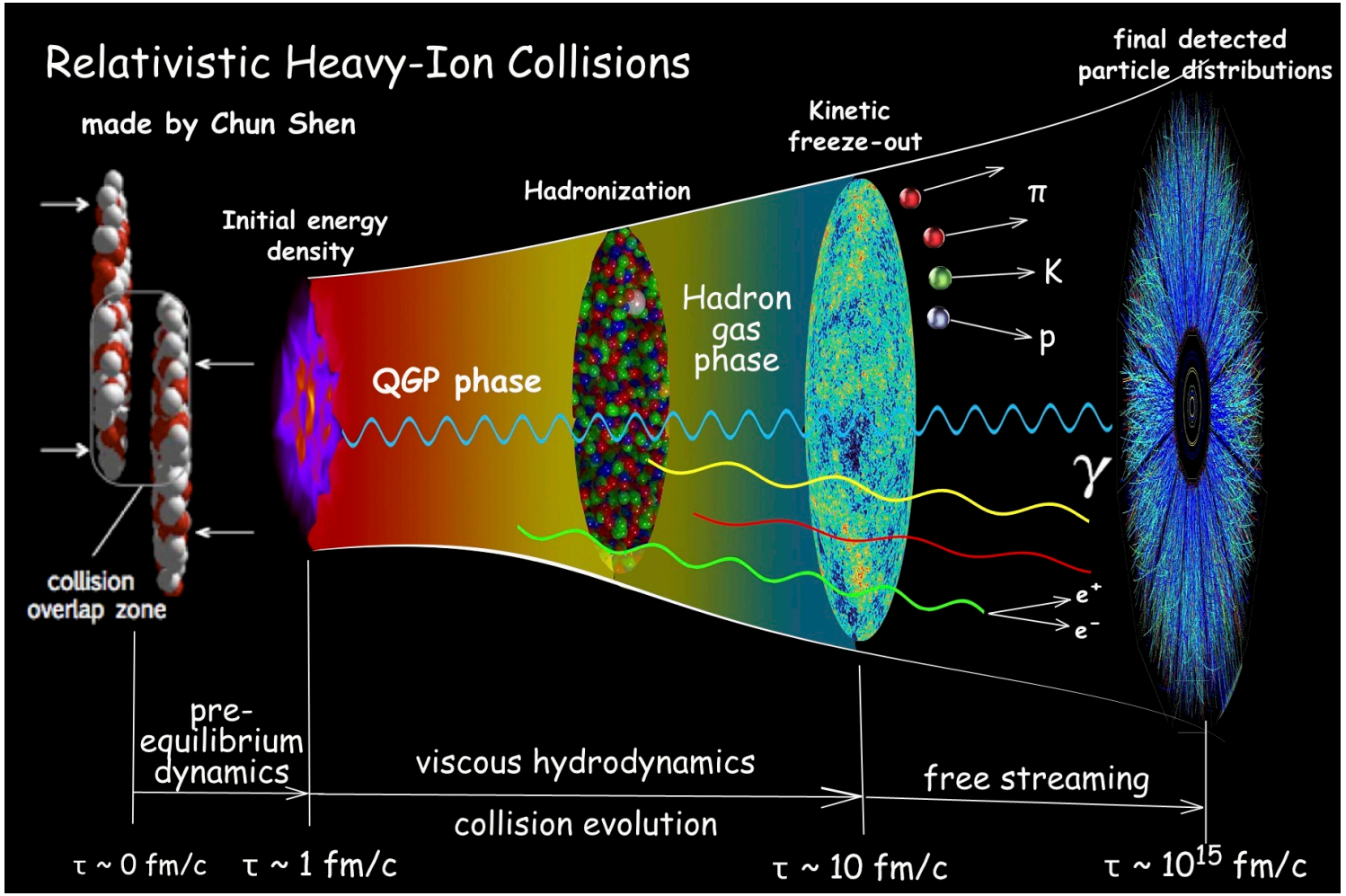
SHANDONG UNIVERSITY

STAR

NSFC

A “Little Bang” in Heavy Ion collision



C.Shen https:// u.osu.edu/vishnu/2014/08/06/sketch-of-relativistic-heavy-ion- collisions

Deconfined QCD matter produced at extreme high temperatures and/or baryon densities

In laboratory : heavy ion collisions

Temperature, as one of key properties of medium, still poorly known

How to measure the temperature

Hadrons
yield , p_T spectra

Statistical thermal models

Hydrodynamics-inspired models

Chemical freeze-out, T_{ch}

Kinetic freeze-out, T_{kin}

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Photons
p_T spectra

Dileptons
M_{ll} spectra

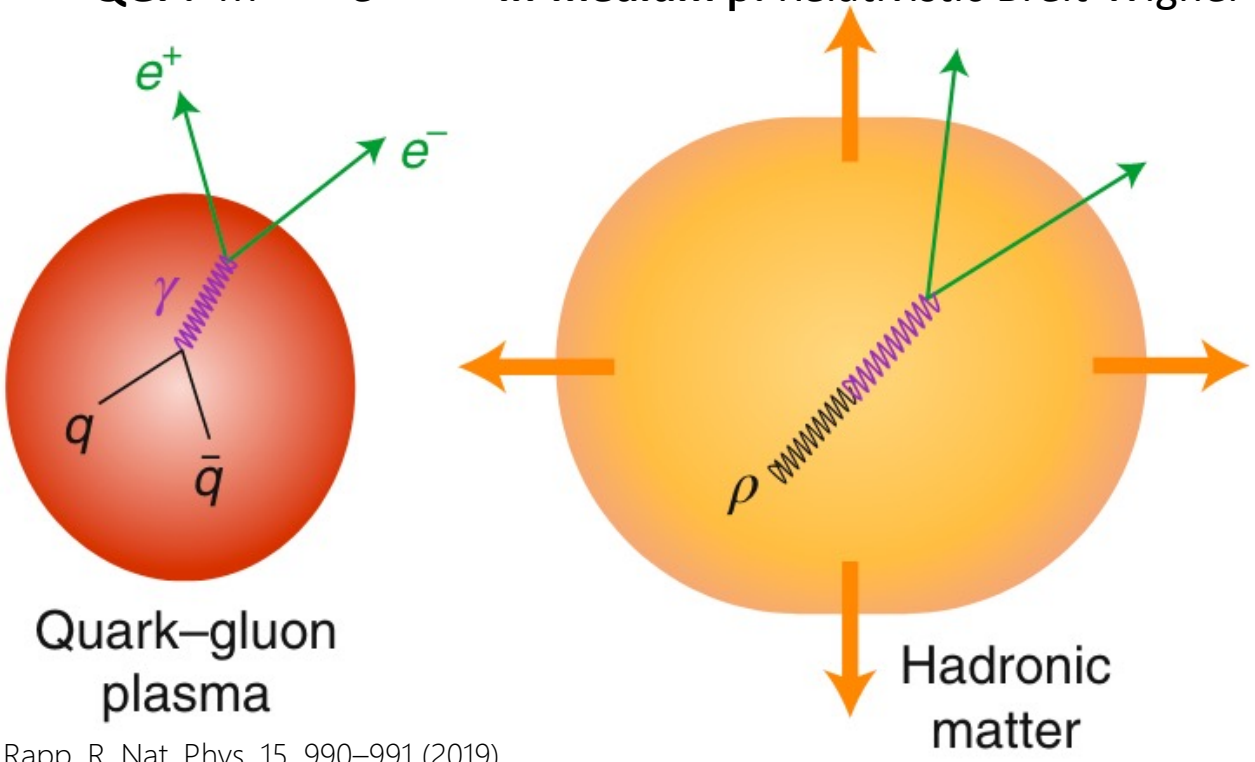
Electromagnetic probes:
- ✓ Minimal interaction with medium
- ✓ Emitting from early stage to final stage

Photons:
- ✓ Extract T_{eff} from p_T spectra
- ✓ $T_{eff} \rightarrow T_{QGP}$: medium flow effect

Dileptons:
- ✓ Temperature measurement without distortion by medium flow effect
- ✓ Only observable to directly access in-medium spectral function

Thermal dileptons

QGP: $M^{3/2} * e^{-M/T}$ **In-medium ρ:** Relativistic Breit-Wigner * $e^{-M/T}$

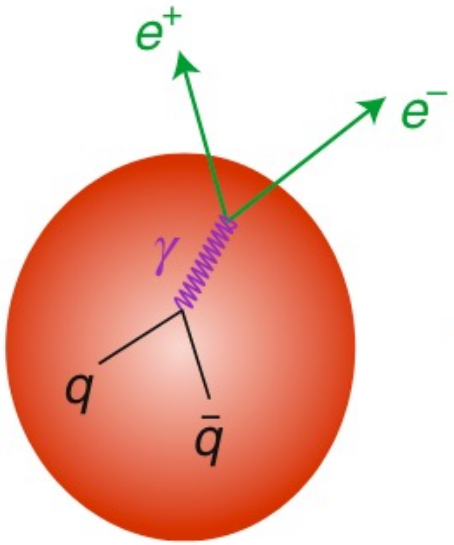


Rapp, R. Nat. Phys. 15, 990–991 (2019).

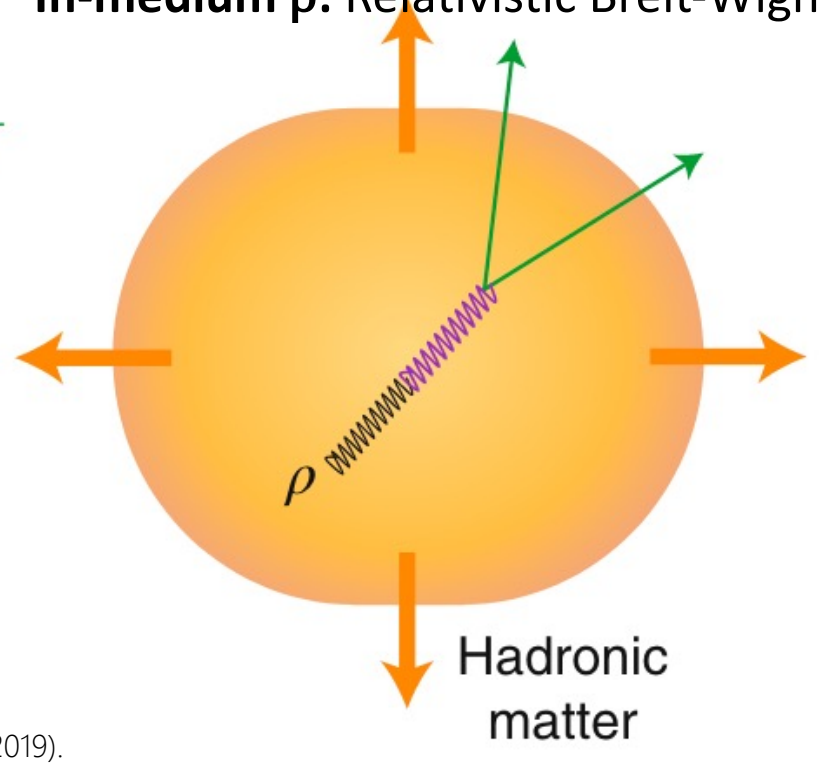
Invariant mass spectra of thermal dileptons can reveal temperature of the hot medium at both **QGP phase** and **hadronic phase**

Thermal dileptons

QGP: $M^{3/2} * e^{-M/T}$ **In-medium ρ:** Relativistic Breit-Wigner $* e^{-M/T}$



Quark–gluon plasma



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inclusive dileptons

Interested signals

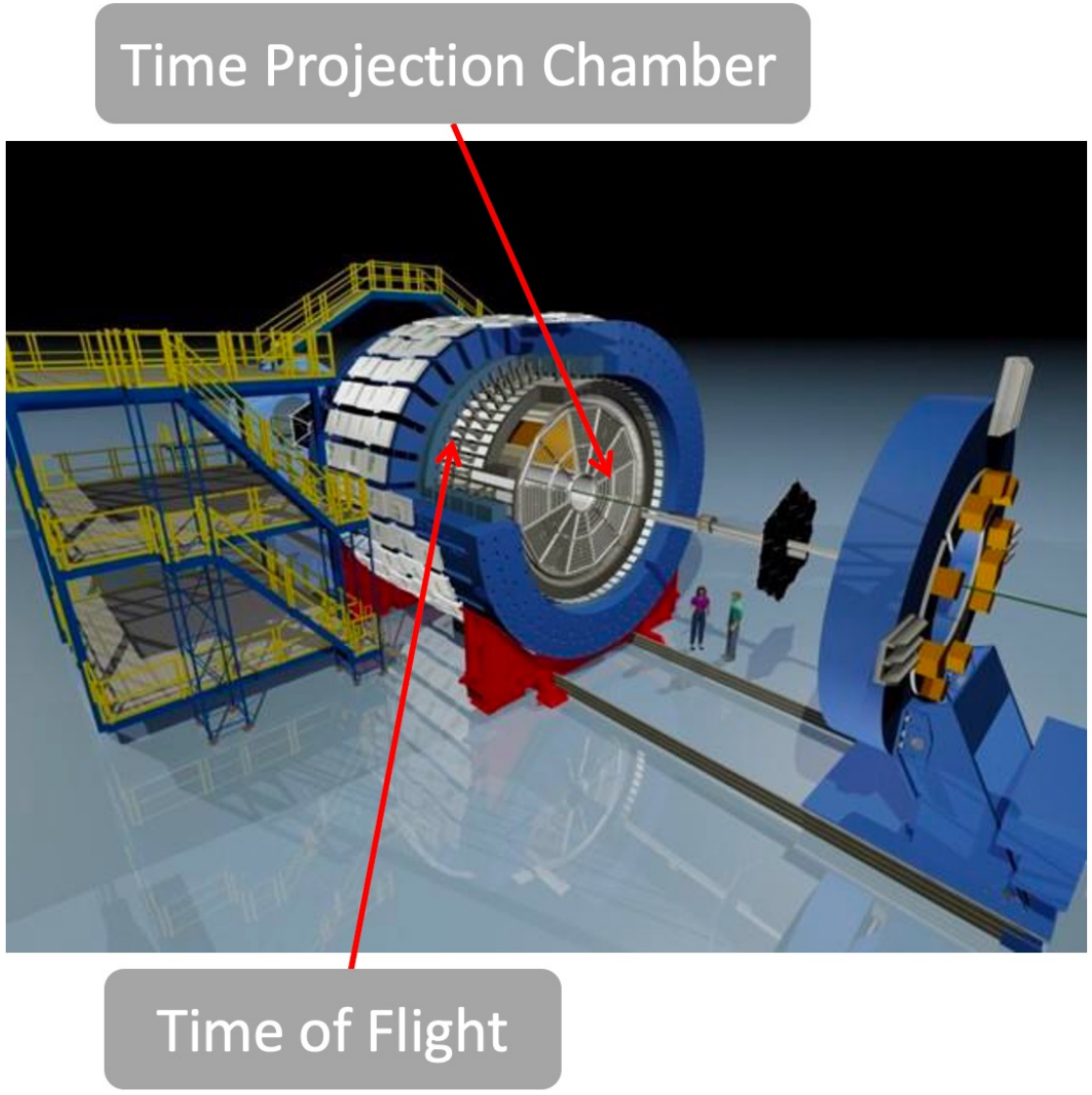
- QGP radiation
- In-medium ρ

Physical backgrounds (hadronic cocktails)

- π^0, η, η' -> γe^+e^-
- ω -> $\pi^0 e^+e^-$
- ϕ -> ηe^+e^-
- ω, ϕ, J/ψ -> e^+e^-
- cc -> e^+e^-X
- Drell-Yan

Invariant mass spectra of thermal dileptons can reveal temperature of the hot medium at both **QGP phase** and **hadronic phase**

STAR experiment and eID

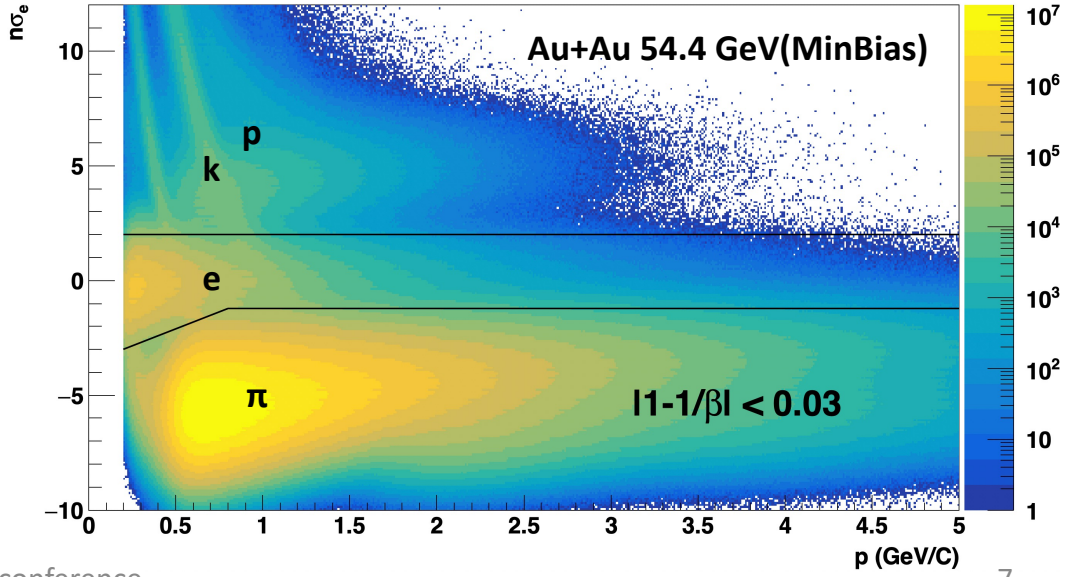


Time Projection Chamber + Time of Flight

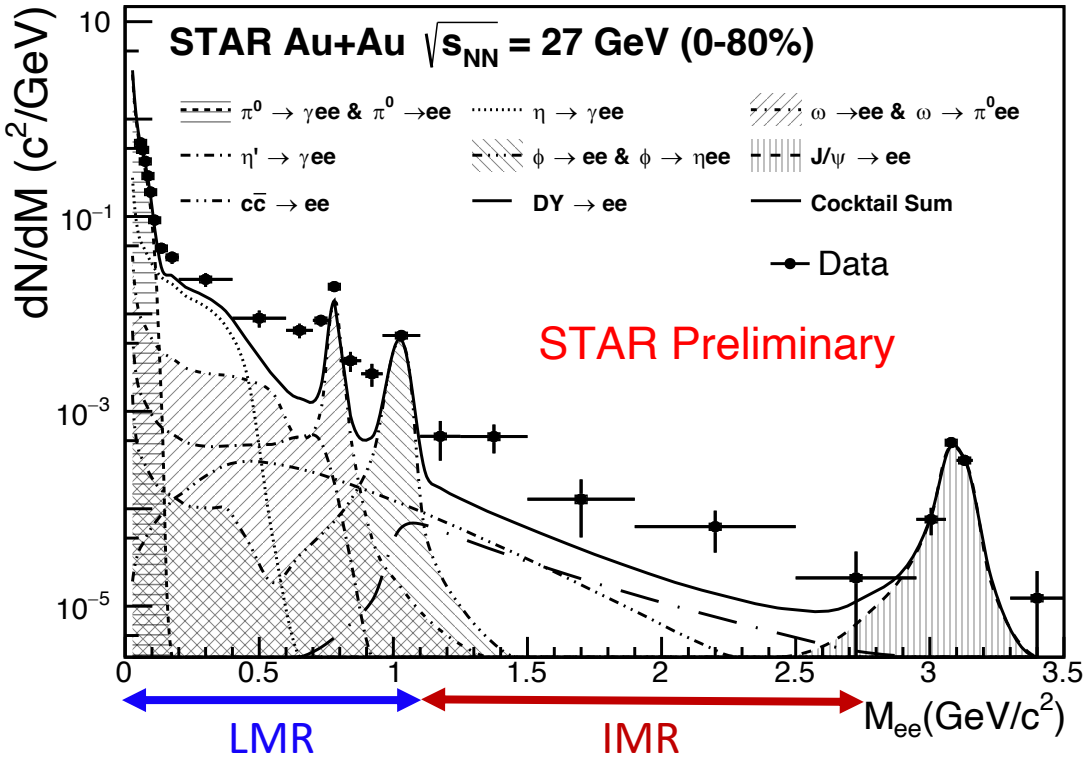
- ✓ Electron identification by dE/dx and velocity
- ✓ High purity electron samples

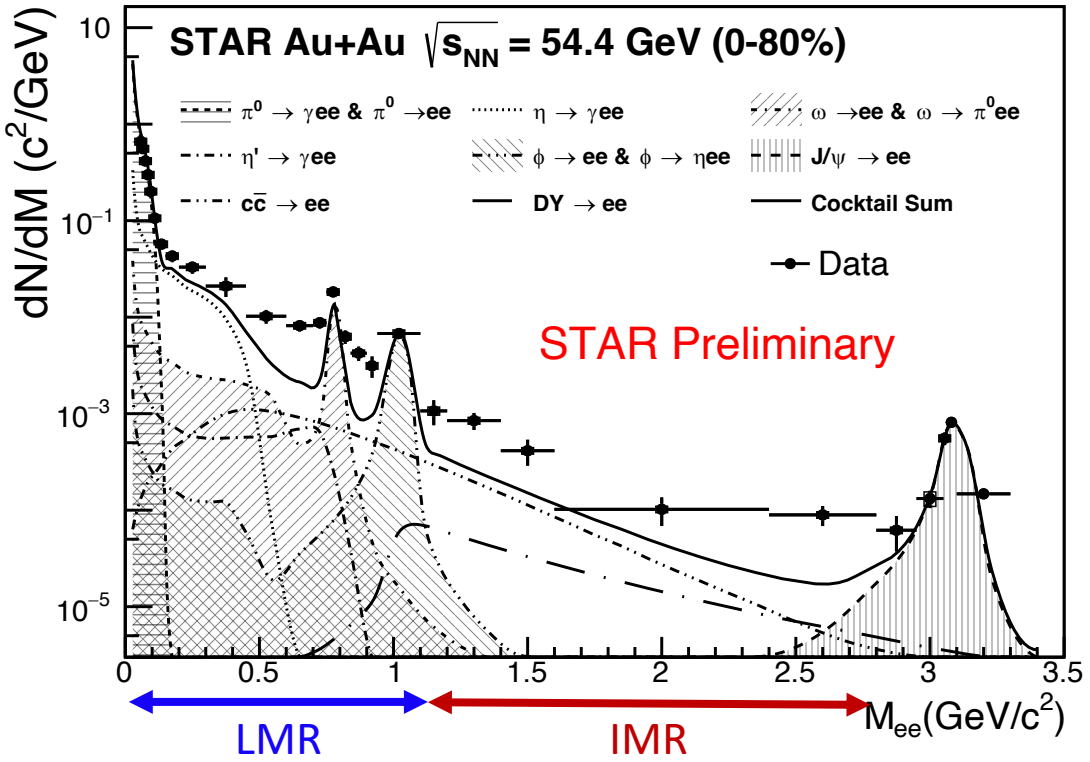
27 and 54.4 GeV dataset

- ✓ Statistics ~ 10 times larger than that in the BES-I 27,39 and 62.4 GeV datasets



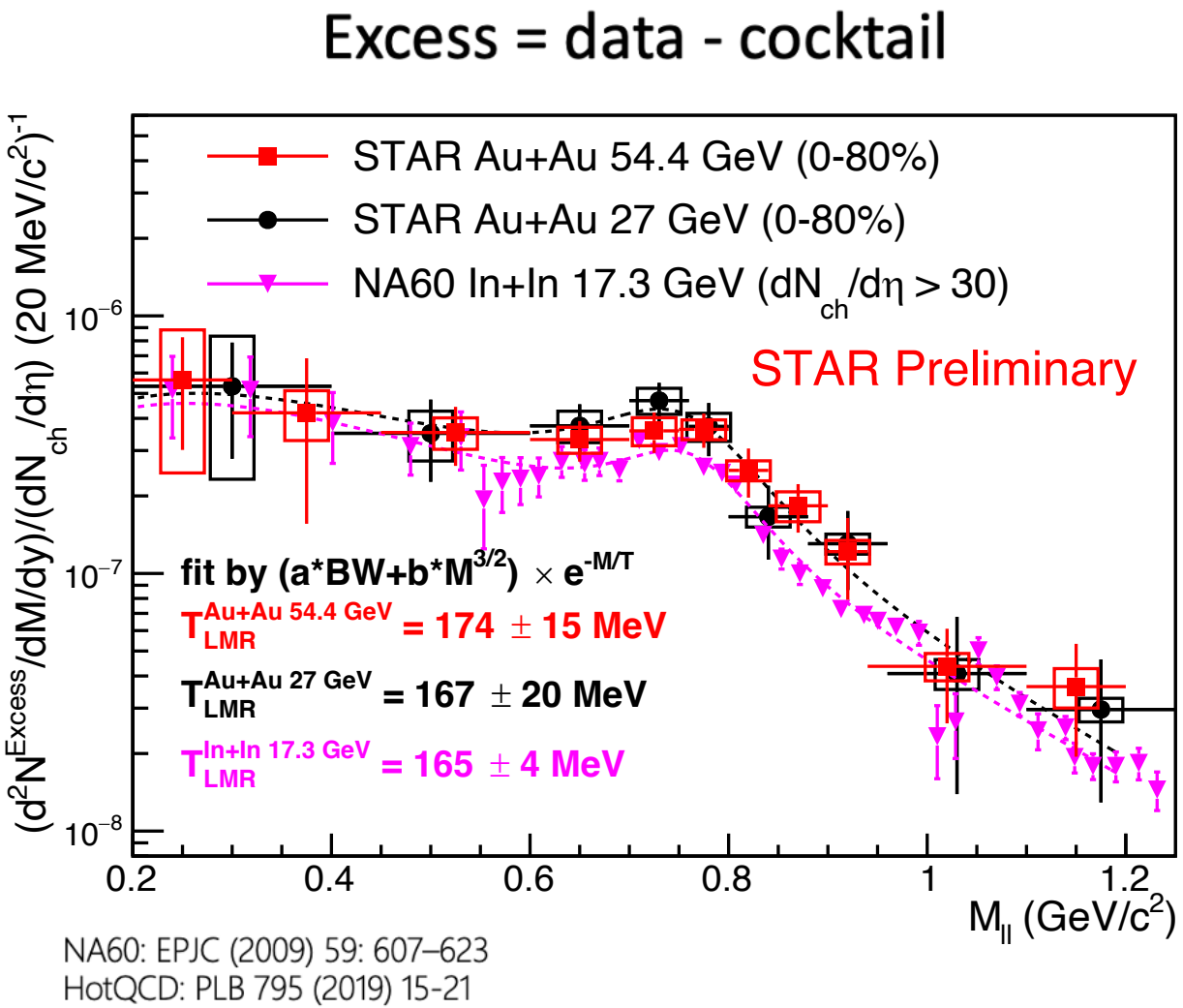
Dielectron spectra





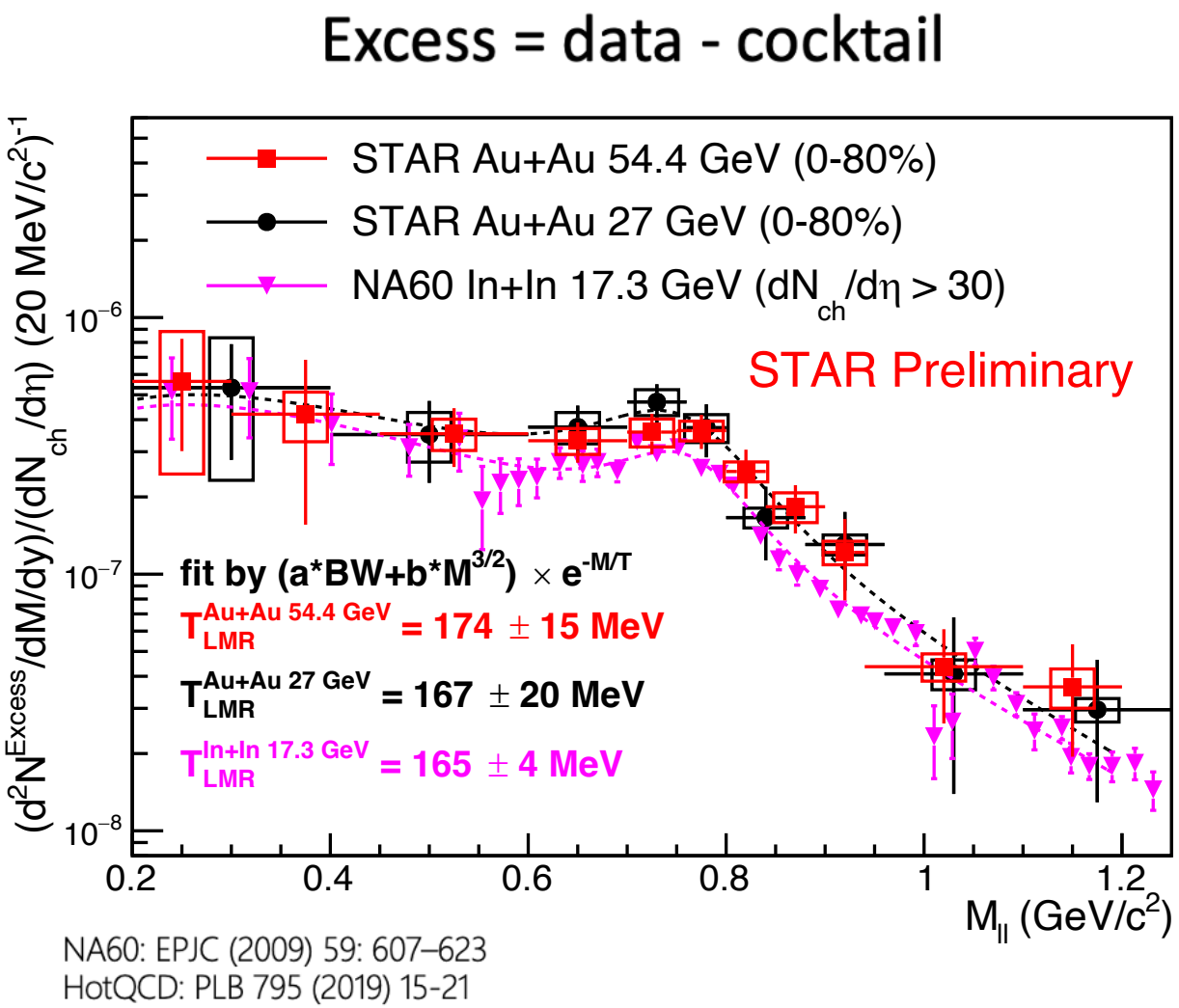
Clear enhancement compared to hadronic cocktail in both low mass region (LMR) and intermediate mass region (IMR)

Temperature extraction from LMR



- ✓ Excess dielectron spectra of 27 and 54.4 GeV Au+Au collisions and 17.3 GeV In+In collisions are similar

Temperature extraction from LMR

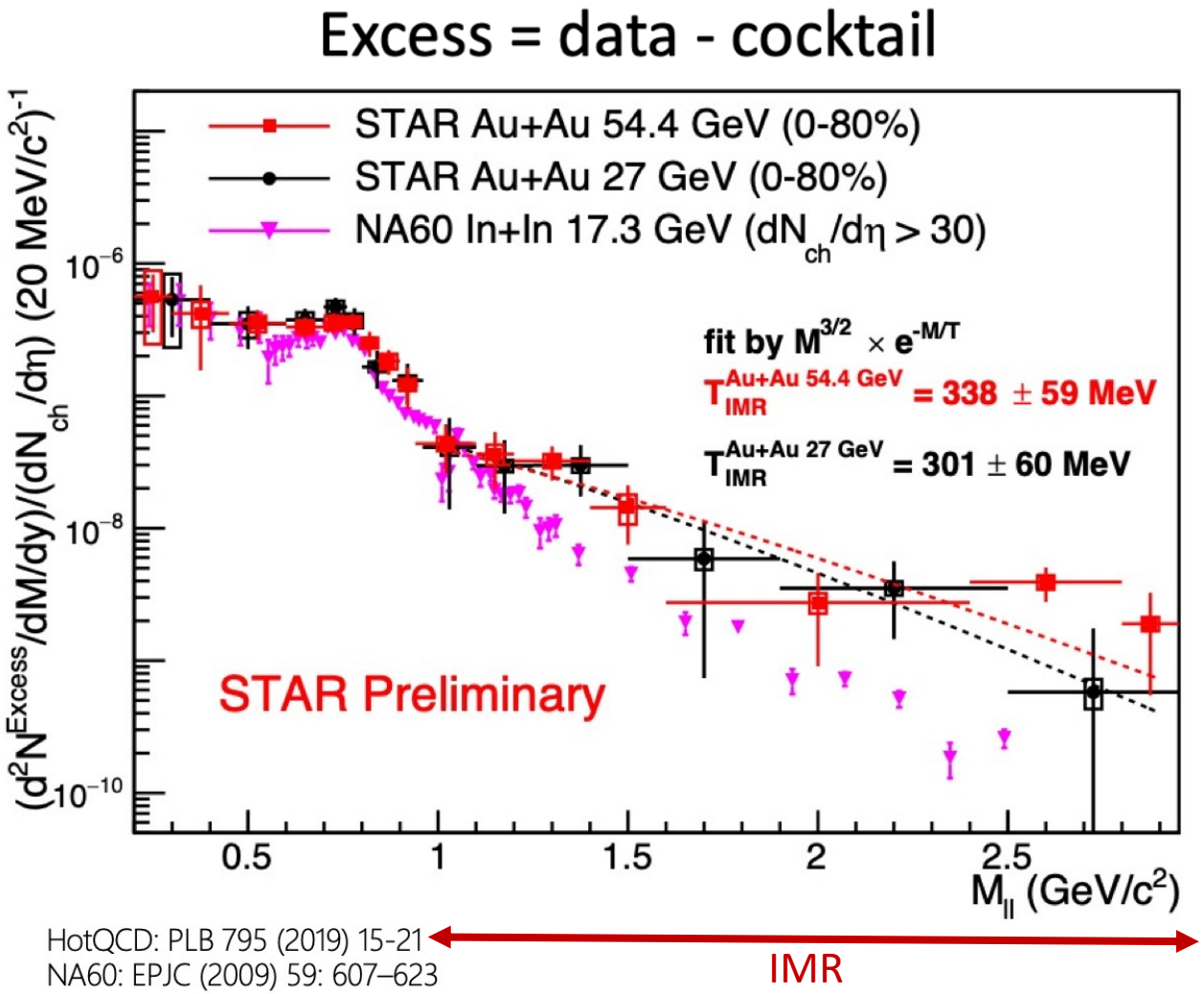


NA60: EPJC (2009) 59: 607–623
HotQCD: PLB 795 (2019) 15-21

Fitting function: $(a*BW + b*M^{3/2})\ e^{-M/T}$

- ✓ Excess dielectron spectra of 27 and 54.4 GeV Au+Au collisions and 17.3 GeV In+In collisions are similar
- ✓ T is similar despite significant differences in collision energies and system sizes
- ✓ T extracted from low mass region is around the pseudo critical temperature T_{pc} (156 MeV)

Temperature extraction form IMR



HotQCD: PLB 795 (2019) 15-21
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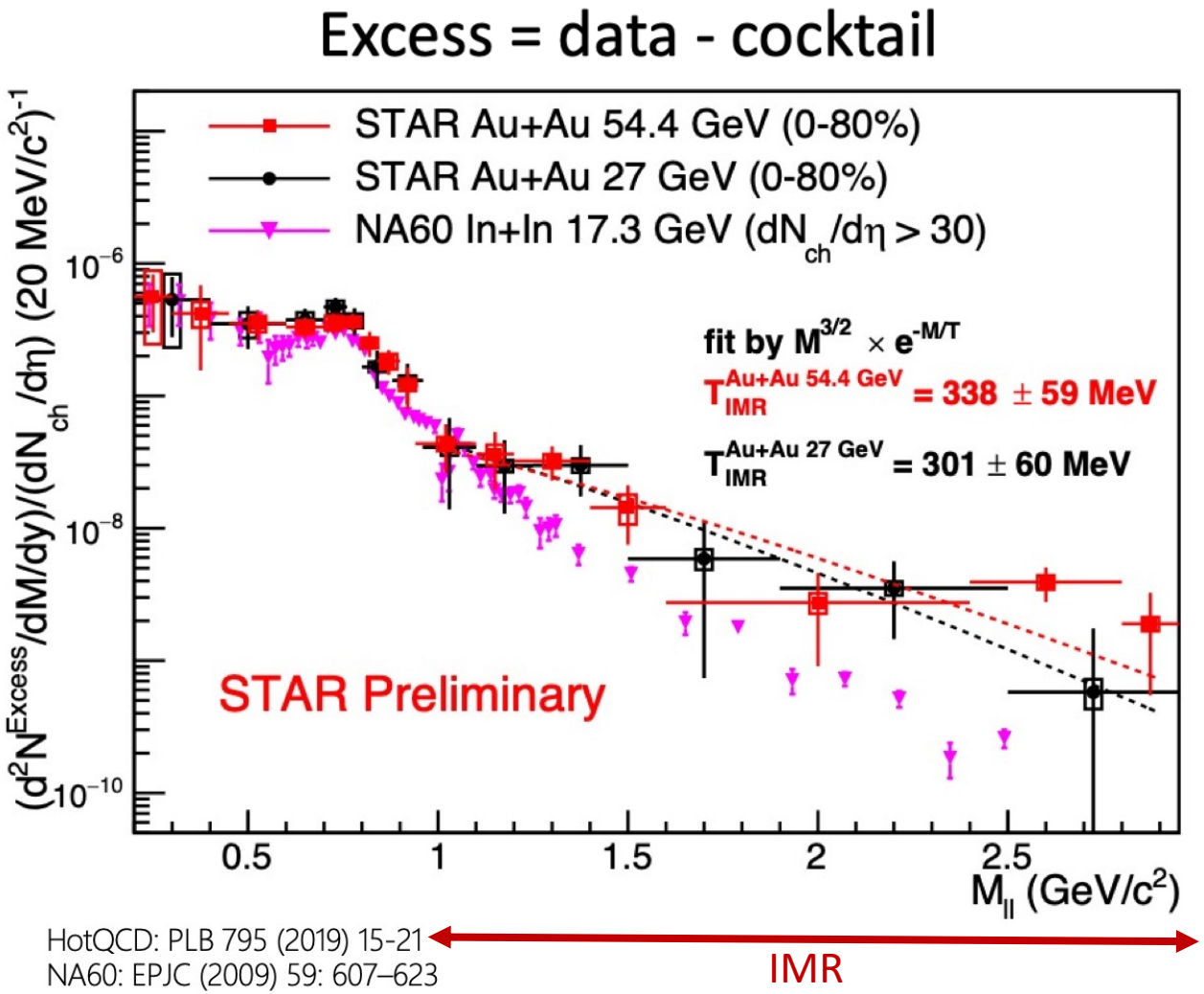
Fitting function: $M^{3/2} * e^{-M/T}$

- ✓ QGP thermal radiation is predicted to be the dominant source in the intermediate mass region
- ✓ T extracted from 27 and 54.4 GeV are consistent with each other

Temperature extraction form IMR



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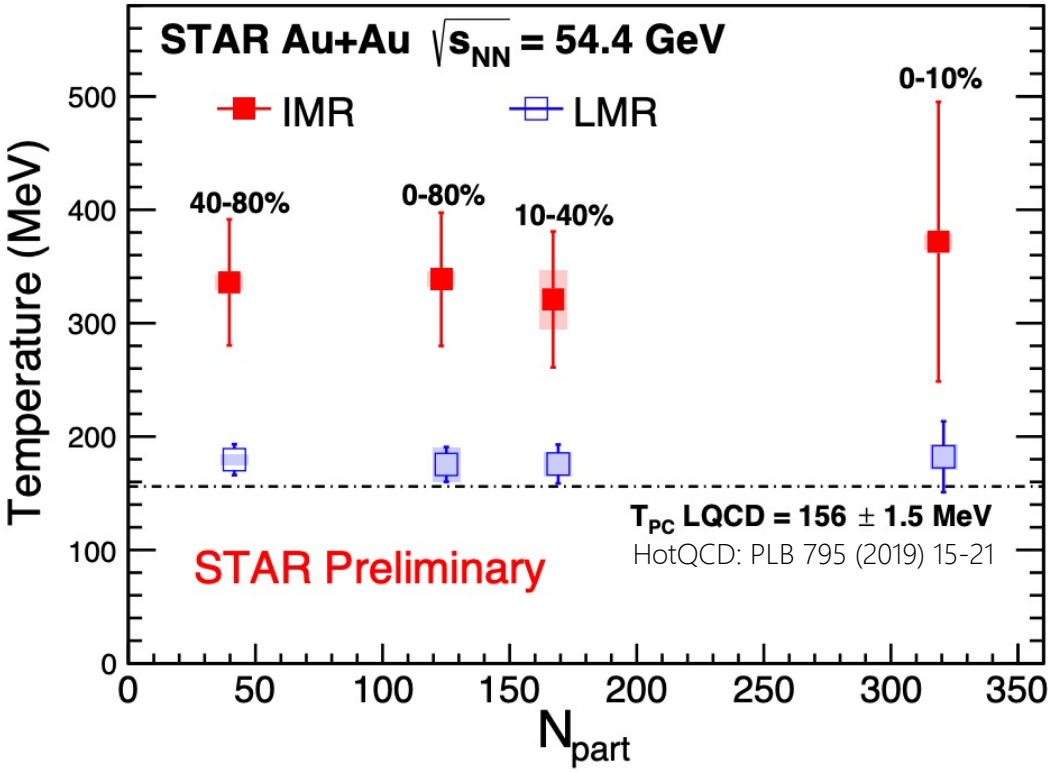
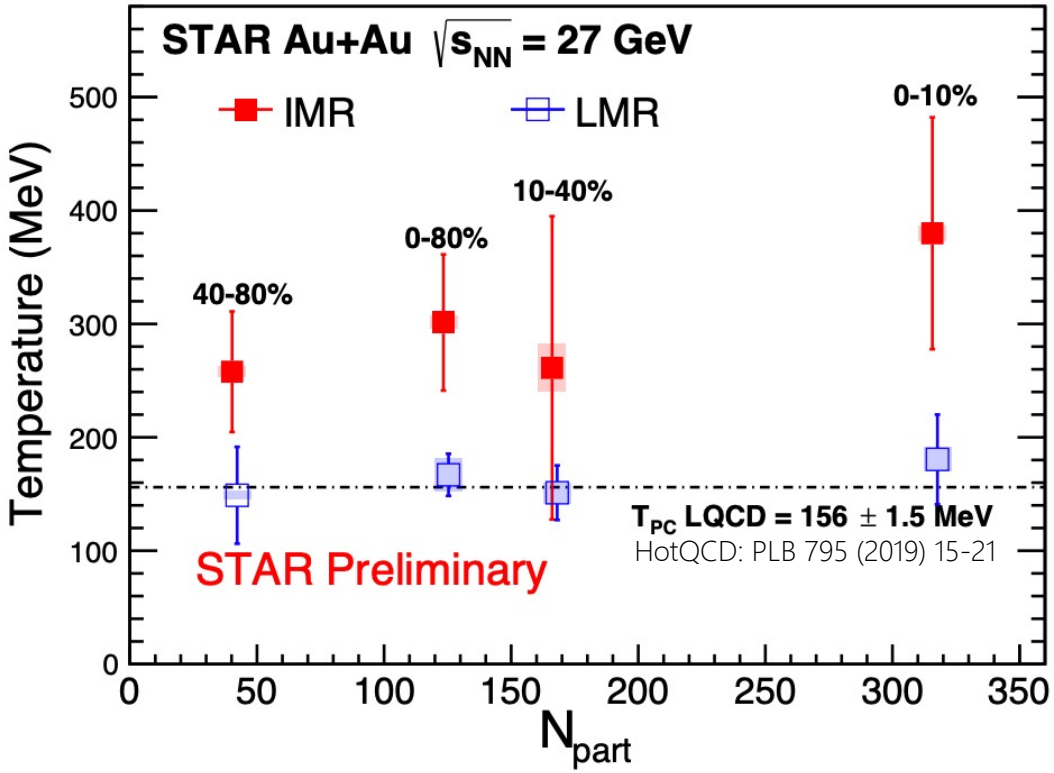
Fitting function: $M^{3/2} * e^{-M/T}$

- ✓ QGP thermal radiation is predicted to be the dominant source in the intermediate mass region
- ✓ T extracted from 27 and 54.4 GeV are consistent with each other
- ✓ T is higher than the pseudo critical temperature T_{pc} (156 MeV), supporting that the emission is predominantly from deconfined partonic phase

Temperature v.s. N_{part}

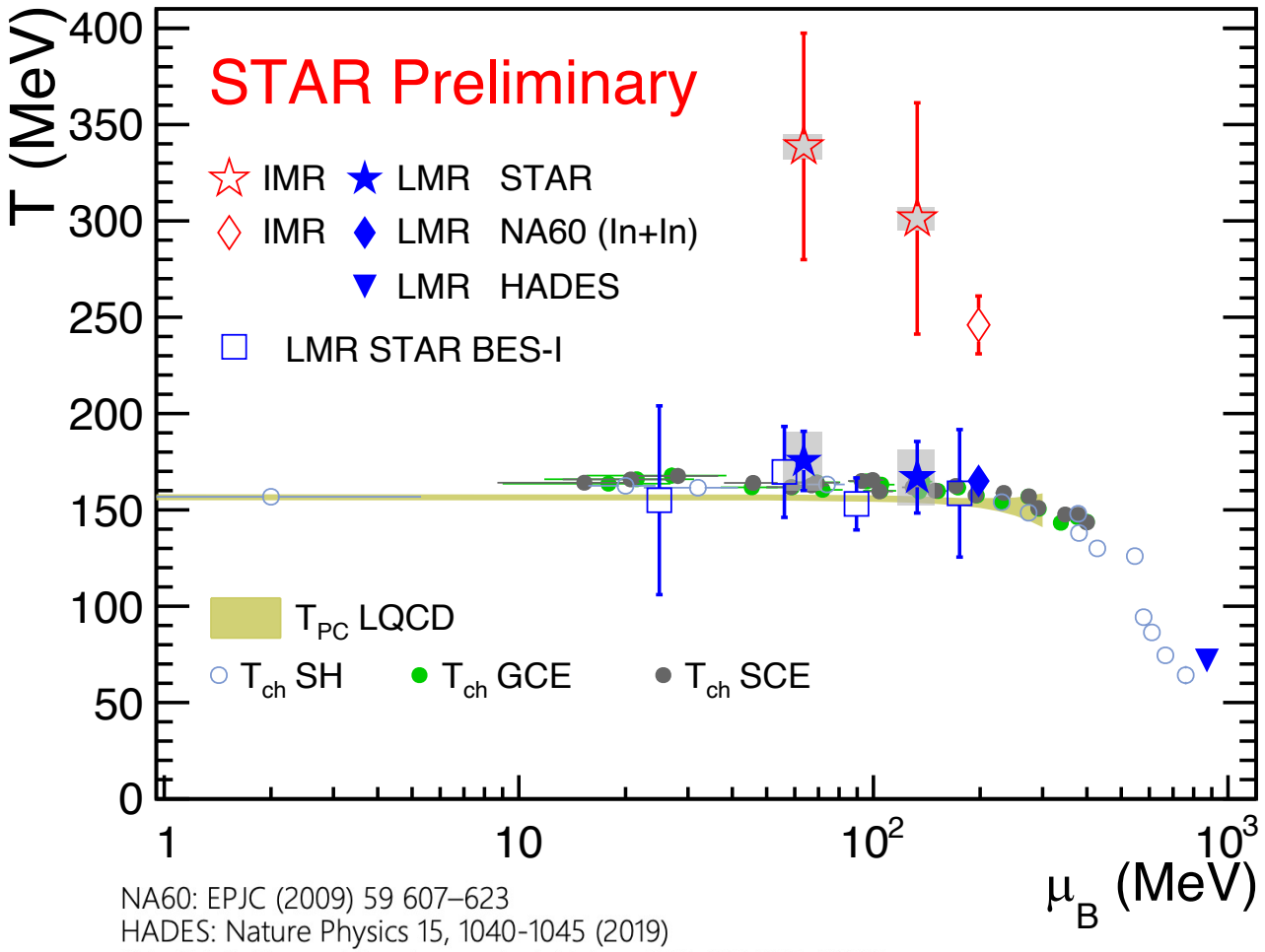




No clear centrality dependence in both mass regions

- ✓ Temperature from low mass region is around the pseudo critical temperature
- ✓ Temperature from intermediate mass region is higher than that in low mass region

Temperature v.s. μ_B



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Tch SH: P. Braun-Munzinger et al. Nature 561, 321-330 (2018)
Tch GCE/SCE: STAR PRC 96, 044904 (2017)

Thermal dielectrons in LMR:

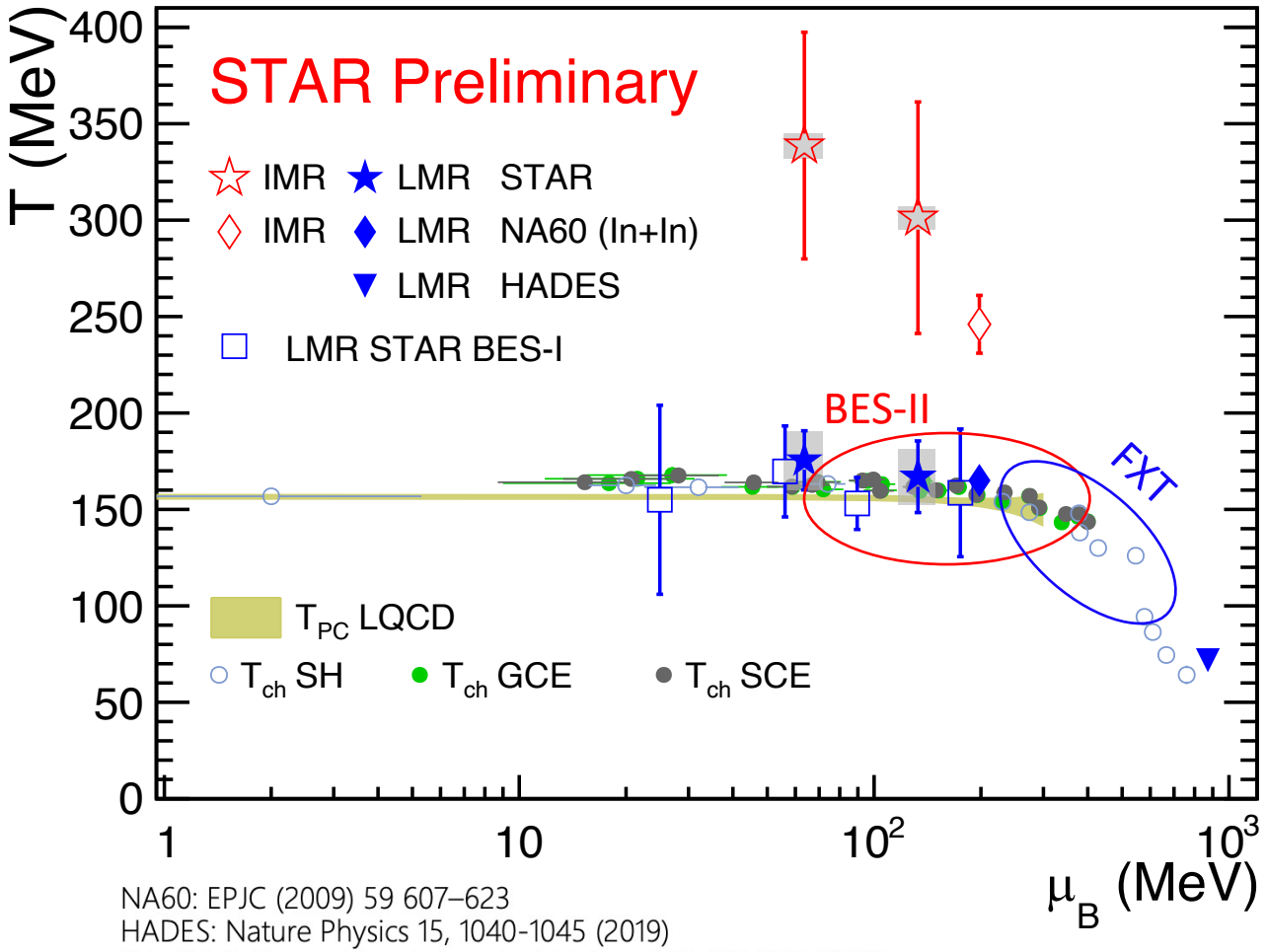
- ✓ T_{LMR} is close to the T_{pc} and T_{ch}
- ✓ Emitted form the hadronic phase, dominantly around the phase transition

Thermal dielectrons in IMR:

- ✓ T_{IMR} is higher than T_{LMR} ,T_{pc} and T_{ch}
- ✓ Emitted form the partonic phase

T_{ch} : Chemical freeze-out temperature
T_{pc} : Pseudo critical temperature

Future dielectron measurements with STAR BES-II and FXT program



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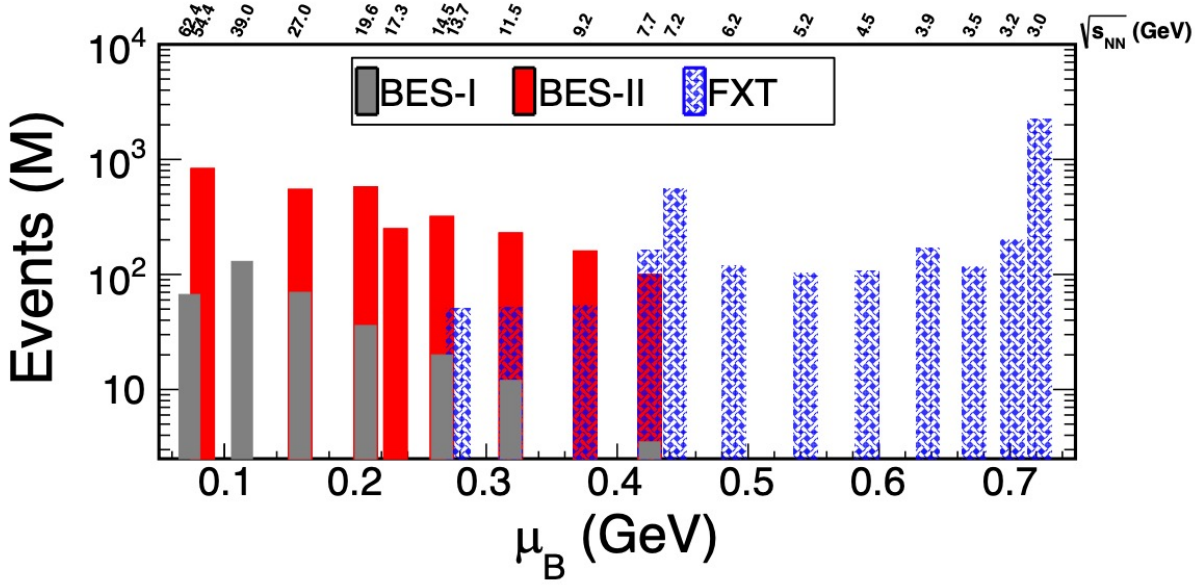
- ✓ Measurements of dielectron spectra with high statistic data samples will be possible with STAR BES-II and FXT program
- ✓ Enhanced tracking and particle indentification capabilities with iTPC and eTOF upgrades



Summary

Low mass region:

- ✓ **T_{LMR} ~ 170 MeV**, first experimental evidence that in-medium ρ is dominantly produced around phase transition

Intermediate mass region:

- ✓ **T_{IMR} ~ 320 MeV**, first QGP temperature measurement at RHIC without distortion by medium flow
- ✓ $T > T_{pc}$, radiation source is QGP thermal radiation