

Thermal Photons at RHIC and LHC

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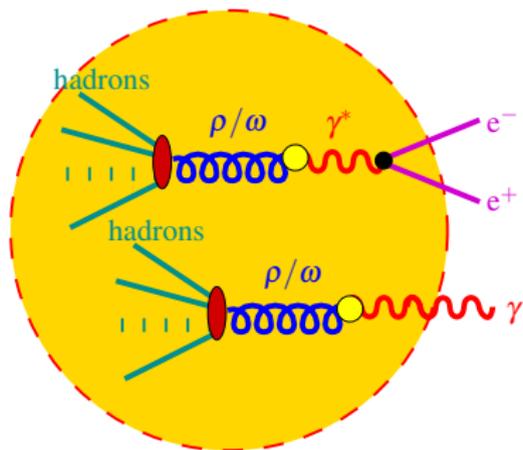
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Why Electromagnetic Probes?

- γ, l^\pm : only electromagnetic interactions
- \Rightarrow negligible final-state interactions
- shines during whole matter evolution
- probes from hot/dense inner region



Photon and dilepton rates from a thermal medium

- **photon** and l^+l^- rates from same **em. current-correlation function**
- medium modification of **vector-meson spectral functions**

$$\Pi_{\mu\nu}^<(q) = \int d^4x \exp(iq \cdot x) \langle J_\mu(0) J_\nu(x) \rangle_T = -2n_B(q_0) \text{Im} \Pi_{\mu\nu}^{(\text{ret})}(q)$$

$$q_0 \frac{dN_\gamma}{d^4x d^3\vec{q}} = -\frac{\alpha_{\text{em}}}{2\pi^2} g^{\mu\nu} \text{Im} \Pi_{\mu\nu}^{(\text{ret})}(q, u) \Big|_{q_0=|\vec{q}|} f_B(p \cdot u)$$

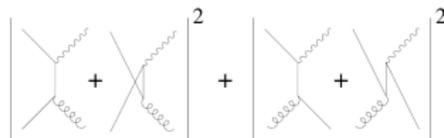
$$\frac{dN_{e^+e^-}}{d^4x d^4k} = -g^{\mu\nu} \frac{\alpha^2}{3q^2\pi^3} \text{Im} \Pi_{\mu\nu}^{(\text{ret})}(q, u) \Big|_{q^2=M_{e^+e^-}^2} f_B(p \cdot u)$$

- it's **not Planck radiation** but carries information about **source: partonic/hadronic em. current correlator!**
- **photon- q_T spectra: blue shift** from flow, u , of source
- radial flow \Rightarrow effective slopes, T_{eff} larger than T
- anisotropic flow $\Rightarrow v_2$ of photons

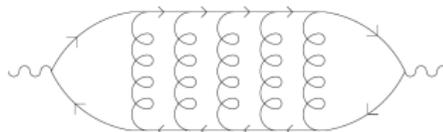
Sources of thermal photons in heavy-ion collisions

- **QGP:** rates from [Arnold, Moore, Yaffe, JHEP 12, 009 (2001)]

- $q\bar{q} \rightarrow \gamma g, qg \rightarrow \gamma q$

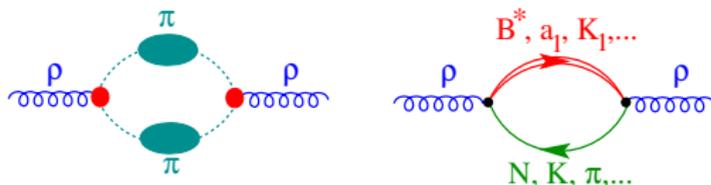


- resummation of soft-gluon bremsstrahlung contributions
- Landau-Pomeranchuk-Migdal effect



- **hadron gas** from [Turbide, Rapp, Gale, PRC 69, 014903 (2004); Rapp, Wambach EPJ A 6, 415 (1999)]

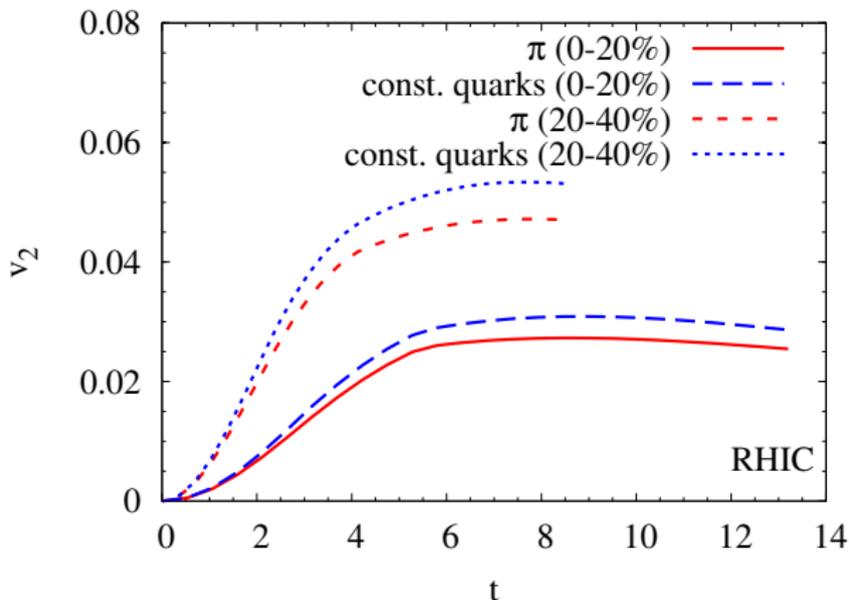
- vector meson-baryon/meson interactions + pion-cloud dressing



- $\pi\rho a_1, \omega$ -t-channel exchange

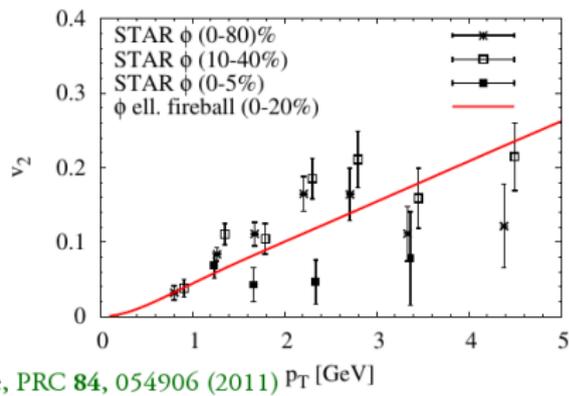
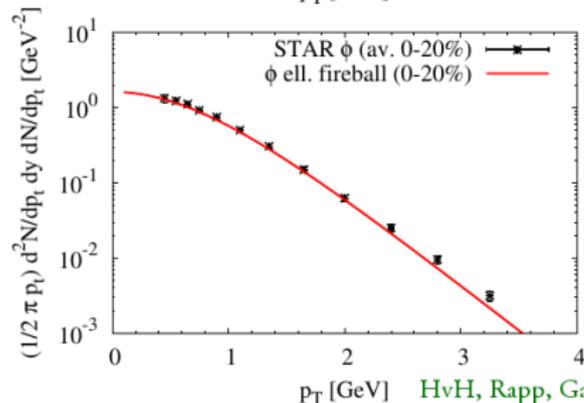
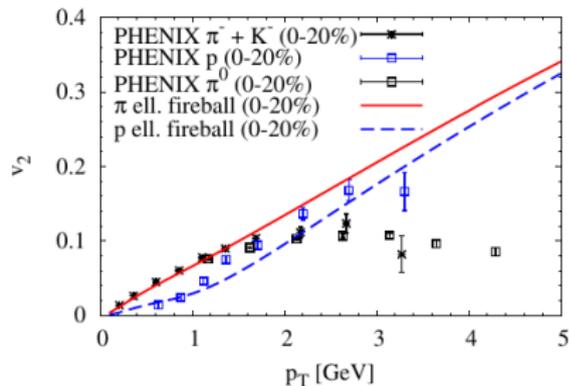
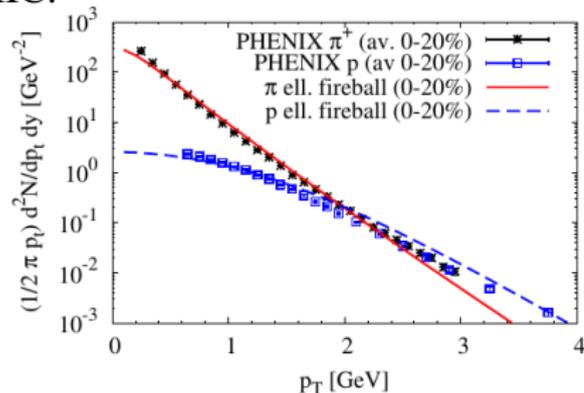
Fireball parametrization

- **thermal** elliptic fireball
- 1st-order equation of state
- isentropic expansion $\Rightarrow T, \mu_B, \mu_\pi, \mu_K$
- early freeze-out of multi-strange hadrons (at $T_c \simeq 180$ MeV)
- can be achieved with (ideal) hydro [He, Fries, Rapp, PRC **85**, 044911 (2012)]



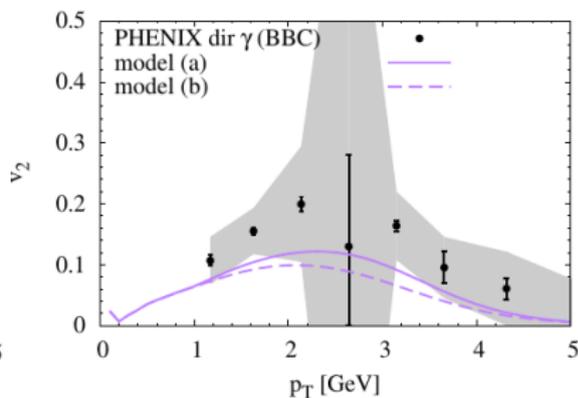
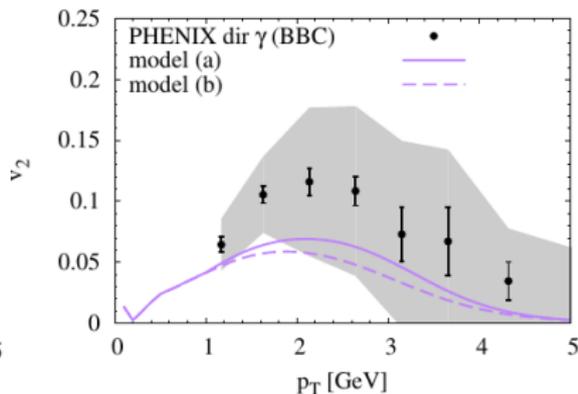
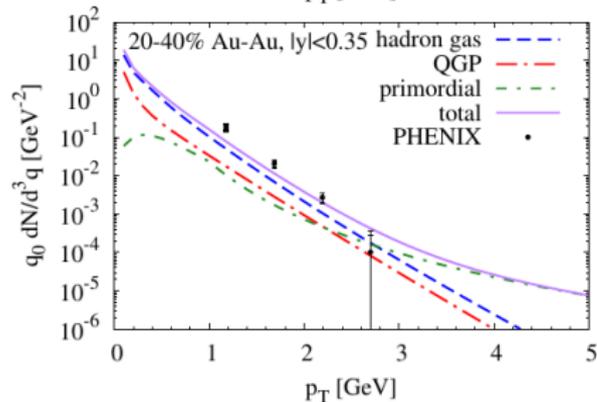
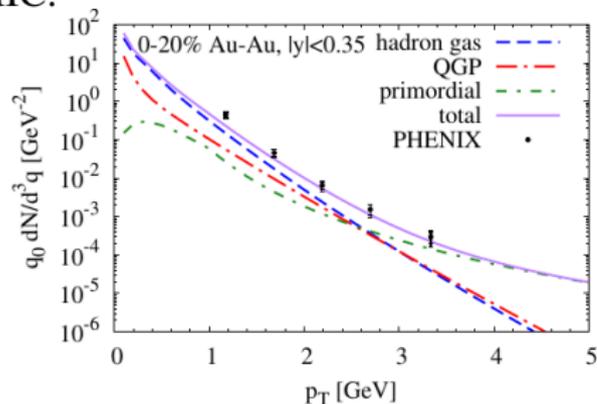
Fireball parametrization

RHIC:



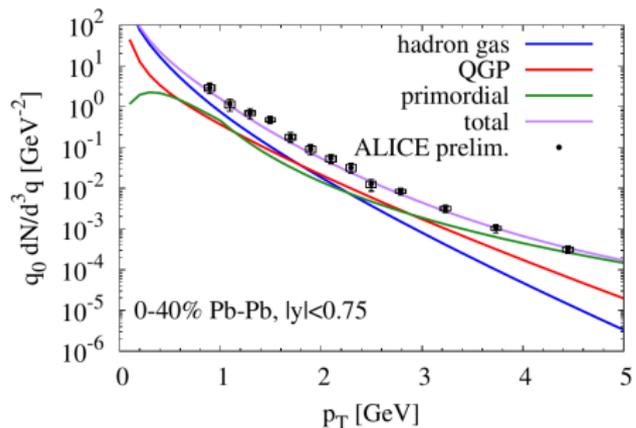
Direct Photons at RHIC

RHIC:

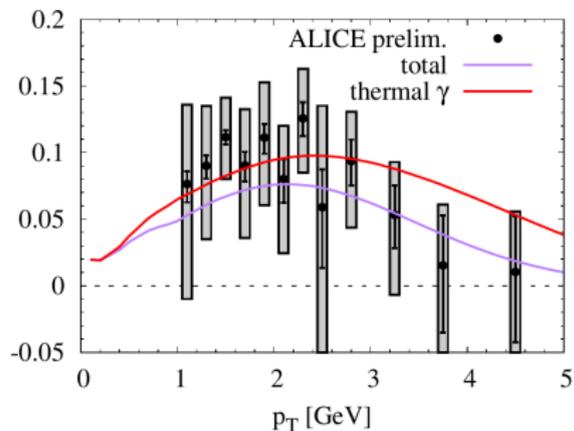


[HvH, Rapp, Gale, PRC 84, 054906 (2011)]

LHC: same model, fireball adapted to hadron data from ALICE



[HvH, Rapp, Gale, unpublished]



- explanation for large direct photon v_2
- emission from **QGP** and **hadron gas** from **hadronic many-body theory**
- pretty large photon yield from **hadronic thermal sources** (RHIC)
- emission from **thermal QGP** dominates at LHC for $p_T \gtrsim 2$ GeV
 - same in-medium model successful for description of dileptons in HICs!
[HvH, Rapp, NPA **806**, 339 (2008); Rapp, Wambach, HvH, Landolt-Börnstein, Volume **I/23**, 4-1 (2010)]
- large p_T slope: **blue shift** due to flowing medium
- sequential hadron freeze-out: multistrange hadrons at T_c
- \Rightarrow early buildup of hadron v_2