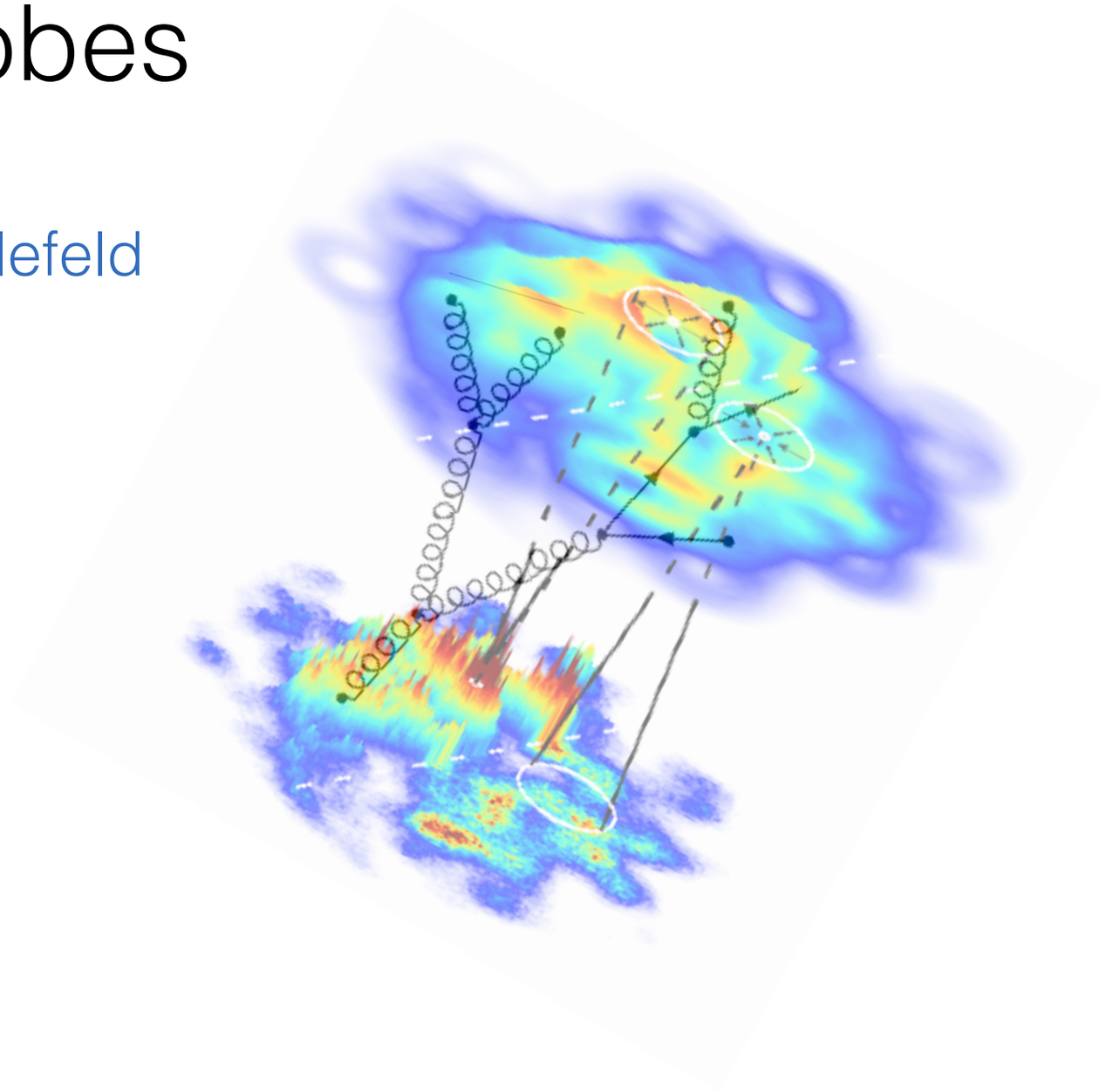
Electromagnetic probes

Sören Schlichting | Universität Bielefeld



CRC-TR 211
Strong-interaction matter under extreme conditions

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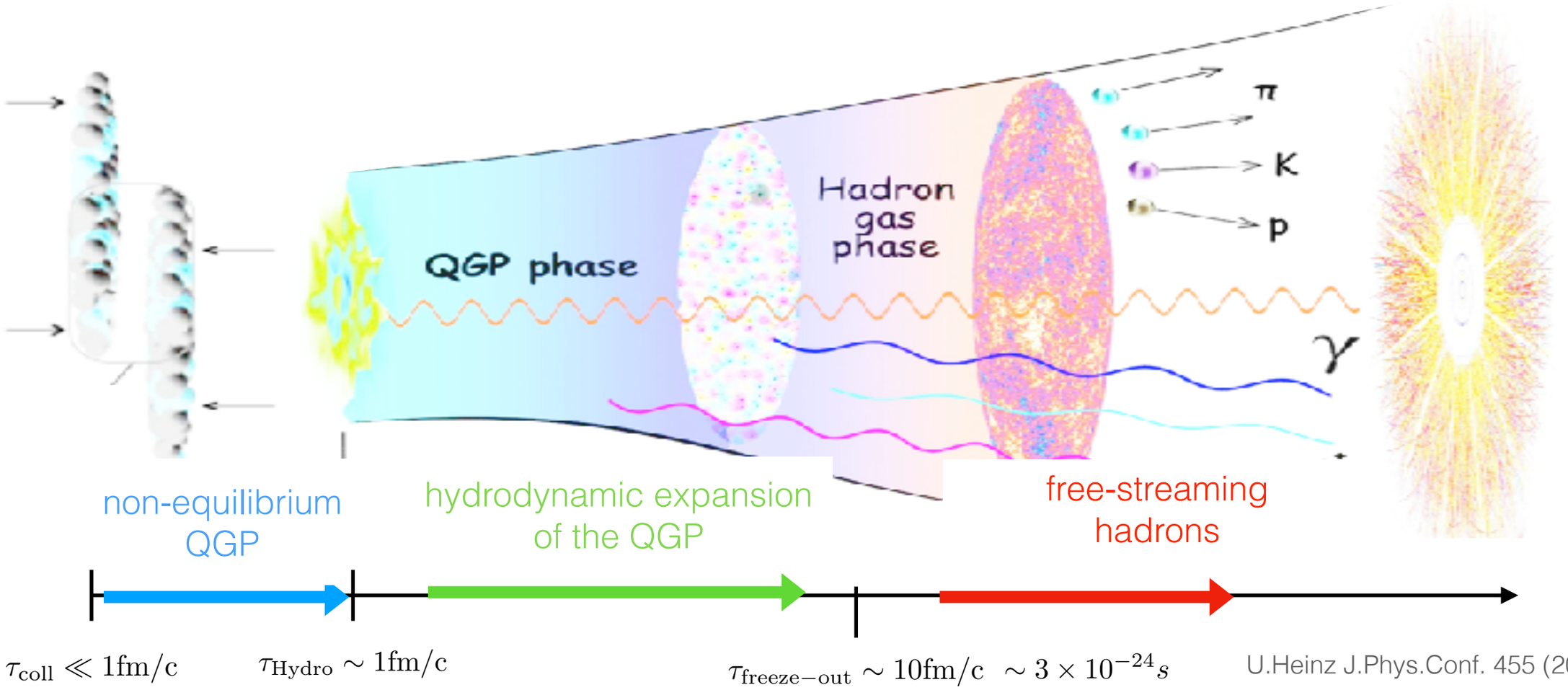
Electromagnetic probes in HIC

Electro-magnetic probes are produced throughout the entire lifetime of the QGP and escape the plasma without re-interaction

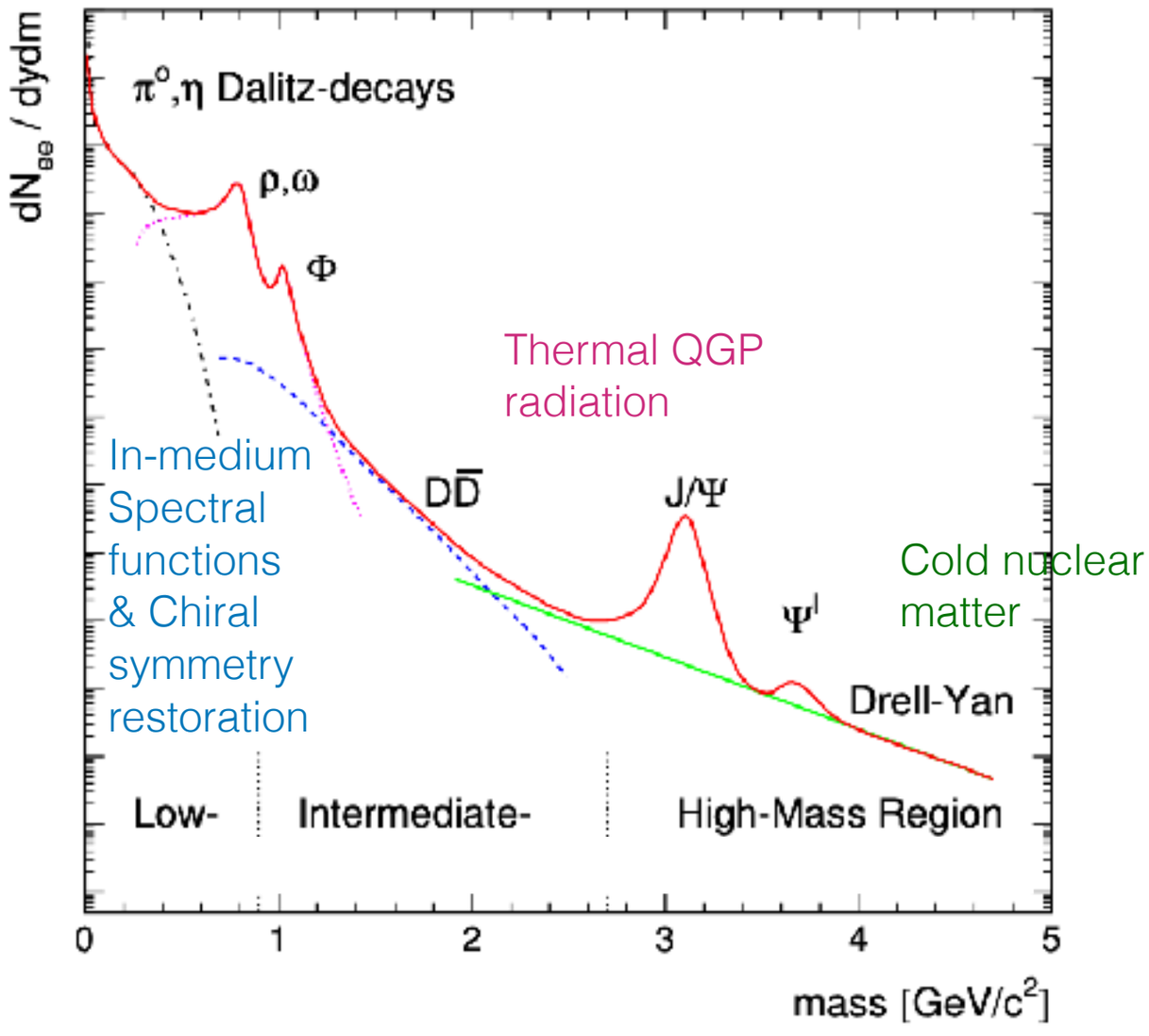


U.Heinz J.Phys.Conf. 455 (2013) 012044

reflect time integrated history of QGP evolution; differential measurements can be used to probe different stages of evolution

Electromagnetic probes in HIC

Dilepton inv. mass spectrum



Rapp, Wambach *Adv.Nucl.Phys. 25 (2000)*

Experimental measurements dominated by backgrounds from various decays

Needs excellent knowledge of background or additional discriminatory power (e.g. heavy-flavour flavour background suppression) to address QGP induced E & M signals

Electromagnetic probes in HIC

Thermal production sensitive to EM spectral function and background QGP evolution

$$\Pi^{\mu\nu}_{\mathrm{em},i} = \mathrm{i}\int \mathrm{d}^4x\, \exp(\mathrm{i}qx)\Theta(x^0)\langle[j^{\mu}_{\mathrm{em},i}(x), j^{\nu}_{\mathrm{em},i}(0)]\rangle$$

Photon production

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

Blue shift of pT spectrum due to radial flow, difficult to disentangle early and late stage production

Dilepton production

$$\frac{\mathrm{d}N_{e^+e^-}}{\mathrm{d}^4x\mathrm{d}^4q} = -g^{\mu\nu}\frac{\alpha^2}{3q^2\pi^3}\,\mathrm{Im}\,\Pi^{(\mathrm{ret})}_{\mu\nu}(q,u)\Big|_{q^2=M^2_{e^+e^-}} f_B(q\cdot u)$$

Different invariant masses M_{ee} give sensitivity to different stages of QGP evolution

Irreducible background from Drell-Yan (require precision)

Dileptons as probe of pre-eq QGP

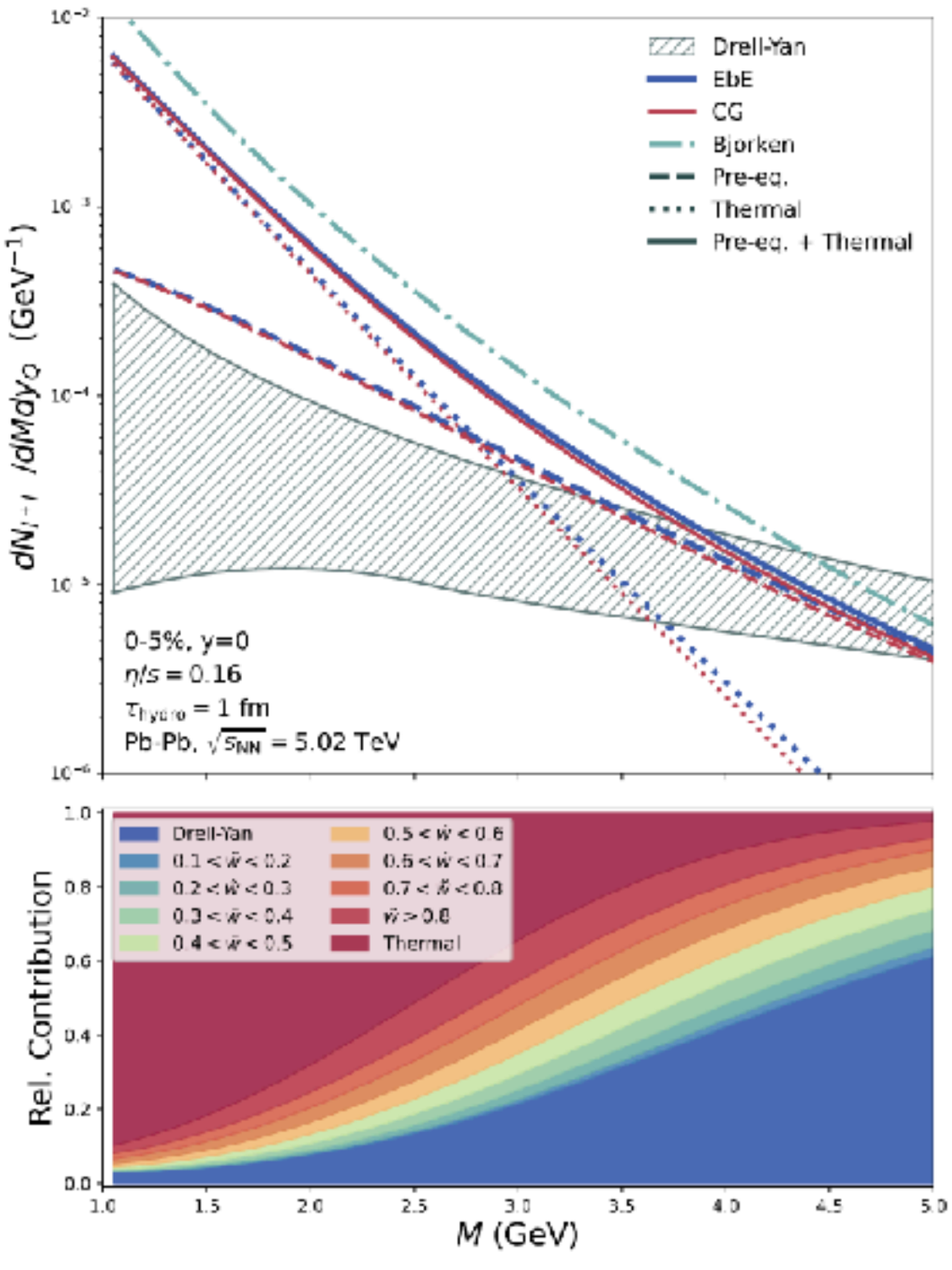
Different invariant masses probe different production times, **including sensitivity to the pre-equilibrium regime**

Dominant pre-equilibrium contribution for M~3GeV

Coquet, Du, Ollitrault, SS, Winn
Phys.Lett.B 821 (2021) 136626
Nucl.Phys.A 1030 (2023) 122579
Phys.Rev.Lett. 132 (2024) 23, 232301

Garcia, Plaschke, SS arXiv:2403.04846

Wu, Du, Gale, Jeon arXiv:2407.04156



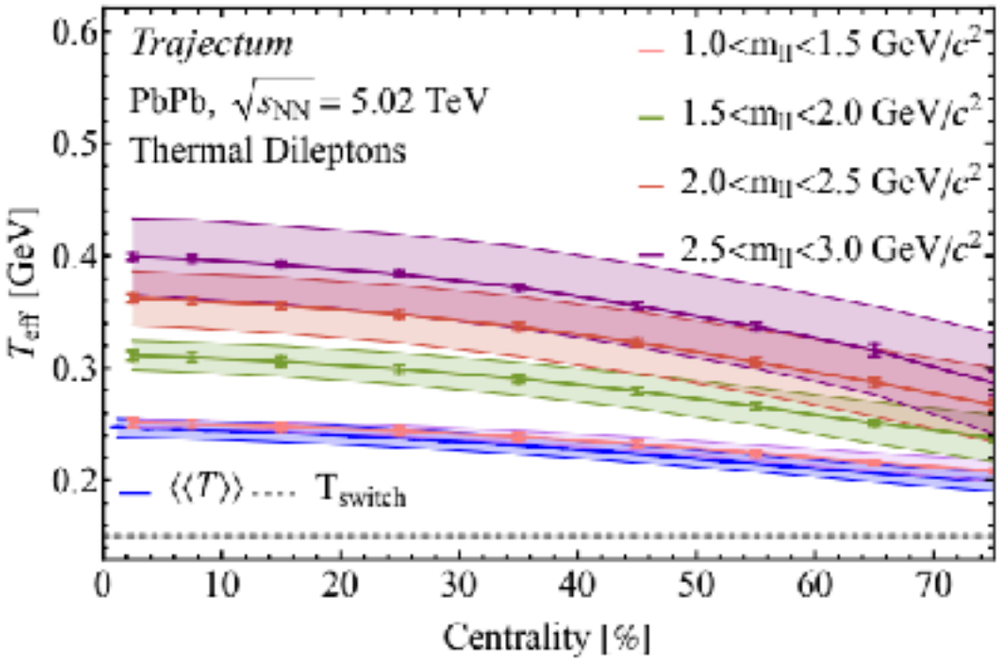
Garcia, Plaschke, SS arXiv:2403.04846

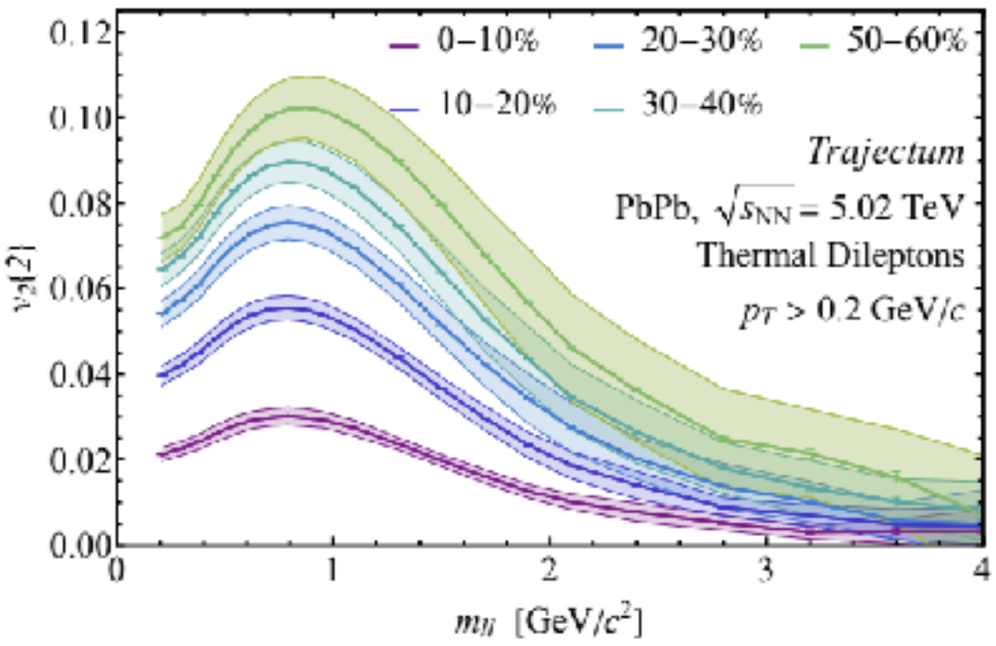
Dilepton flow

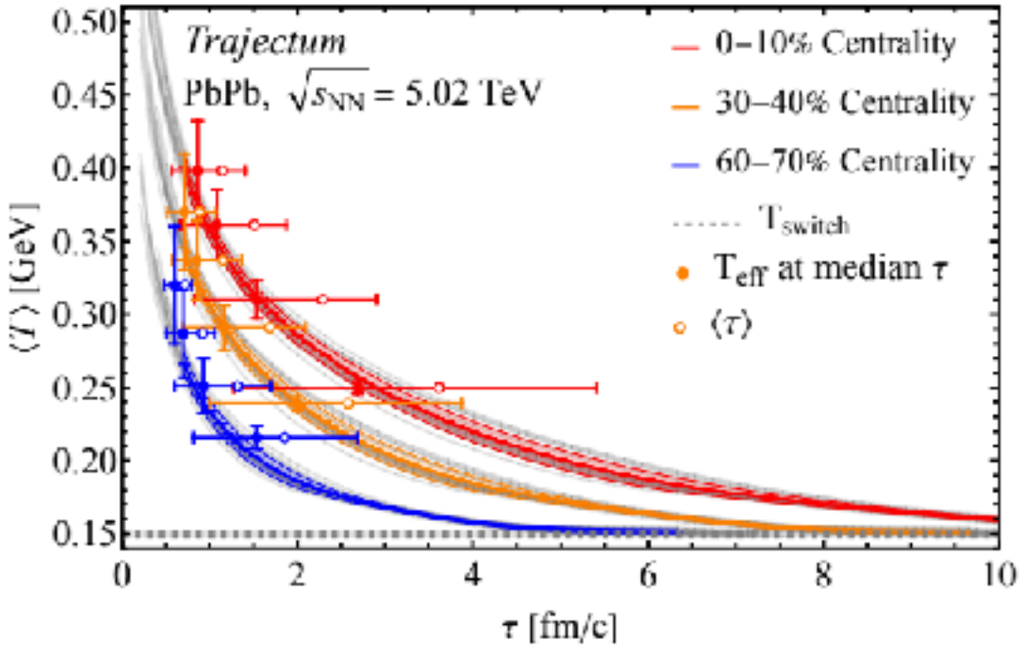
Can probe **time dependence of QGP bulk evolution** with Dileptons, e.g. $v_2(M)$

Massen, Nijs, Sas, vdSchee, Snelling
arXiv:2412.09671

Kasmaei, Strickland
Phys.Rev.D 99 (2019) 3



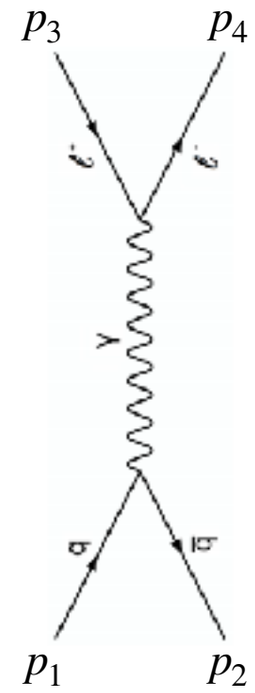




Dilepton polarization as measure of QGP bulk anisotropy

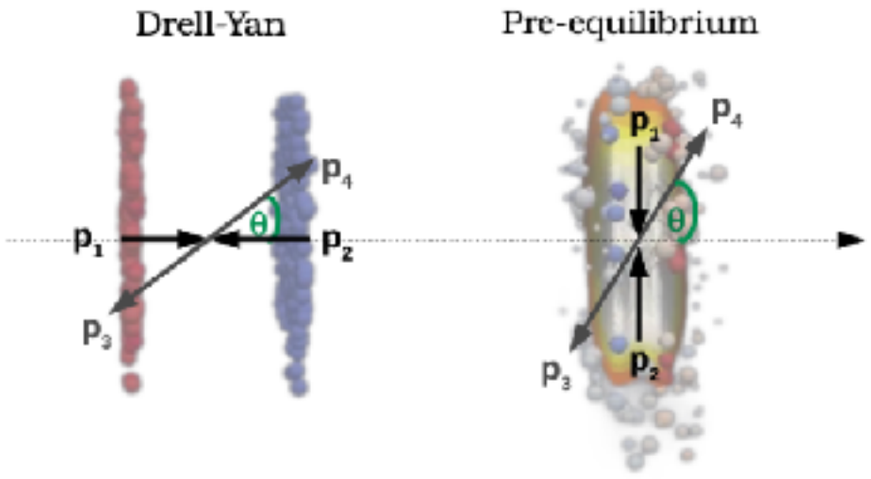
Evaluated in Dilepton rest frame

$$p_1 = (|\vec{q}|, \vec{q}) \quad p_2 = (|\vec{q}|, -\vec{q}) \qquad p_3 = (|\vec{l}|, \vec{l}) \quad p_4 = (|\vec{l}|, -\vec{l})$$



opening angle of lepton pair, preferentially aligned with opening angle of quark pair

$$E_3 E_4 \frac{dN}{d^3 p_3 d^3 p_4} \sim |q||l|(1 + \cos(\theta)^2_{ql})$$



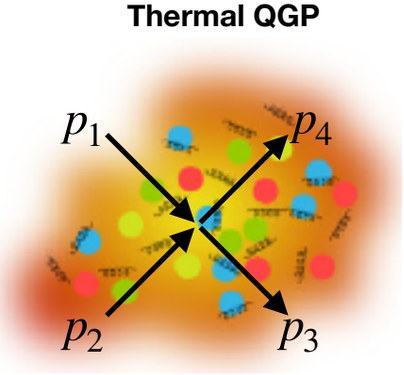
Measured by Polarisation in Collins-Soper frame (dilepton rest frame with z-axis along beam)

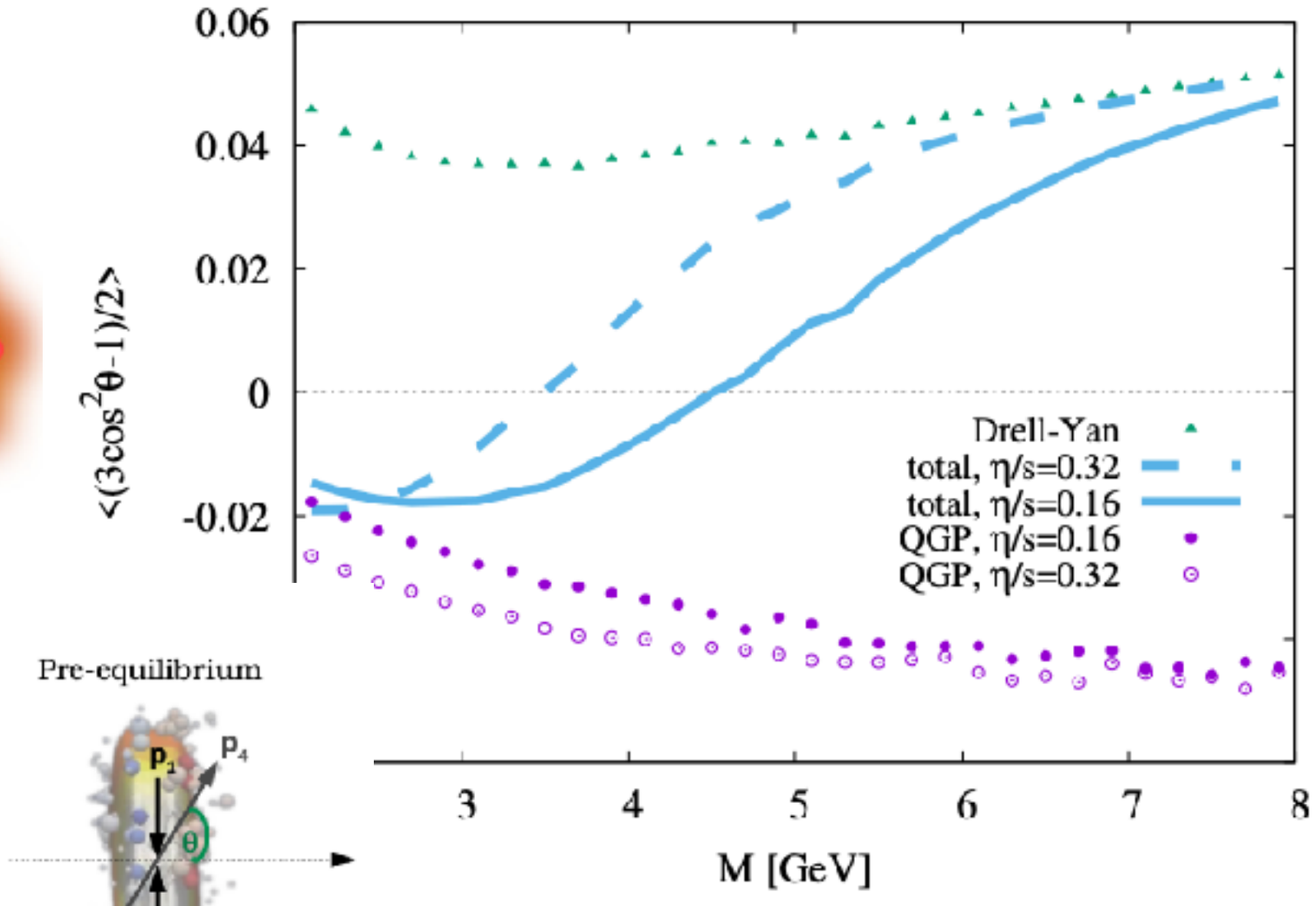
$$\cos\theta = \left.\frac{p_4^z}{|\mathbf{p}_4|}\right|_{\text{CS frame}} = \frac{2\left(E_3 p_4^z - E_4 p_3^z\right)}{M\sqrt{M^2 + p_T^2}},$$

Dilepton polarization as measure of QGP bulk anisotropy

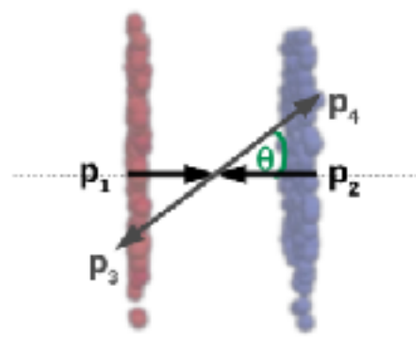
Coquet, Du, Ollitrault, SS, Winn *Phys.Rev.Lett.* 132 (2024) 23, 232301

Thermal QGP





Drell-Yan



Pre-equilibrium

If accessible, this would be the first measurement of QGP bulk anisotropy at early times