Improved screening at zero baryon density

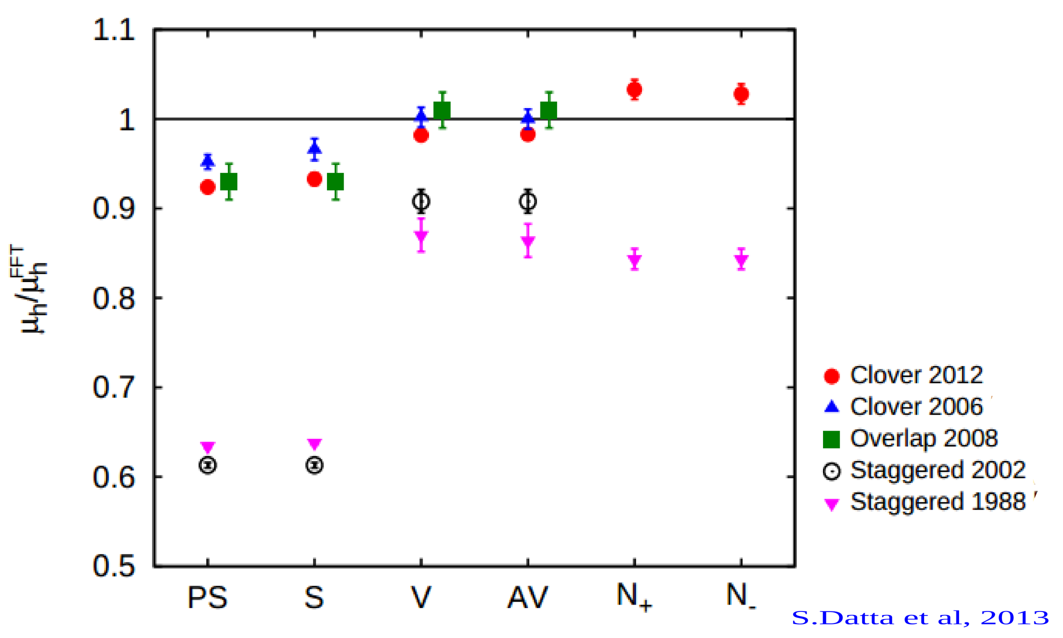
Sourendu Gupta and Nikhil Karthik

Department of Theoretical Physics, Tata Institute of Fundamental Research, Mumbai 400005, India

Problem

$$\langle \hat{O}_l^\dagger(z)\,\hat{O}_l(0)\rangle \sim \exp(-z/\xi_l)$$

Screening mass μ_l is the inverse of the static correlation length ξ_l measured from spatial correlators. In the high temperature phase of QCD, staggered pseudoscalar (PS) and scalar (S) screening masses never seemed to approach the free field theory (FFT) limit. Also, staggered PS and S screening masses seemed to lie below FFT, contradictory to weak coupling prediction. We try to resolve these issues by improving the $\mathcal{O}(\alpha_S a^2)$ taste symmetry violations with gauge link smearing.

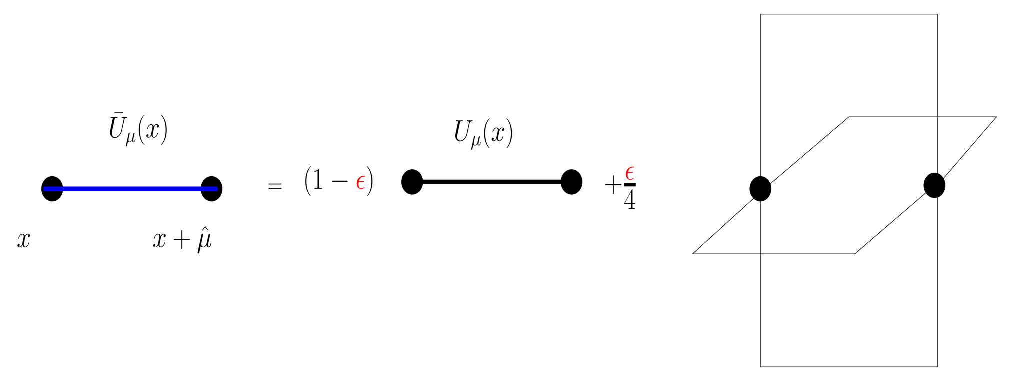


Improving taste symmetry

The staggered pion has 16 taste partners ($\Gamma_{\rm spin}\otimes\Gamma_{\rm taste}$). The pion taste spectrum, $m_{\Gamma_{\rm taste}}$, is split by $\mathcal{O}(\alpha_S a^2)$ lattice artifacts. We reduce the taste splitting

$$\delta m_\pi = m_{\gamma_5\gamma_i} - m_{\gamma_5}.$$

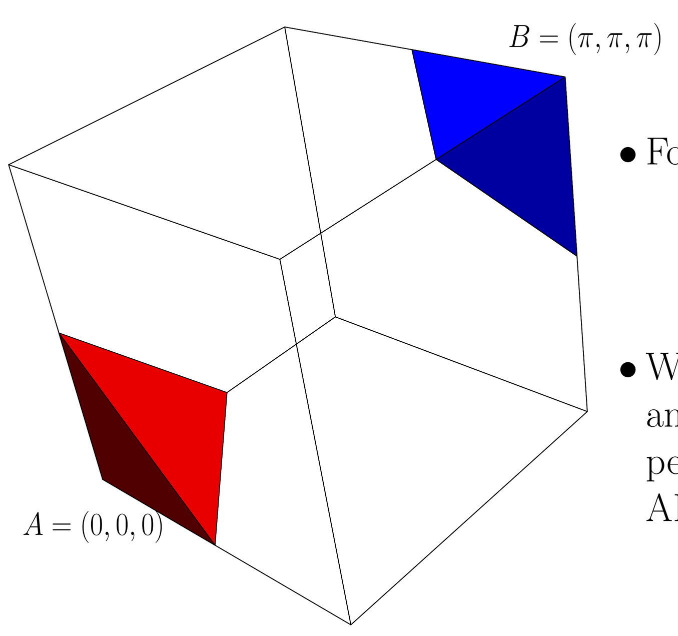
using gauge link smearing.



We used four different different schemes: **APE** (M. Albanese *et al.* 1987), **Stout** (C. Morningstar and M. J. Peardon, 2004), **HYP** (A. Hasenfratz and F. Knechtli, 2001) and **HEX** (S. Capitani *et al.* 2006).
Unitary projection for APE and HYP using polar decomposition.

Optimization of smearing

Protect long distance physics: Tune smearing parameter, ϵ, such that ultraviolet (UV) is suppressed while infrared (IR) is least affected.



- Fourier modes of plaquette, $P(x)$:

$$c(k) = \sum_x P(x)\exp(ik.x)\,.$$

- We divided the modes into IR, UV and generic modes using planes perpendicular to body diagonal AB.

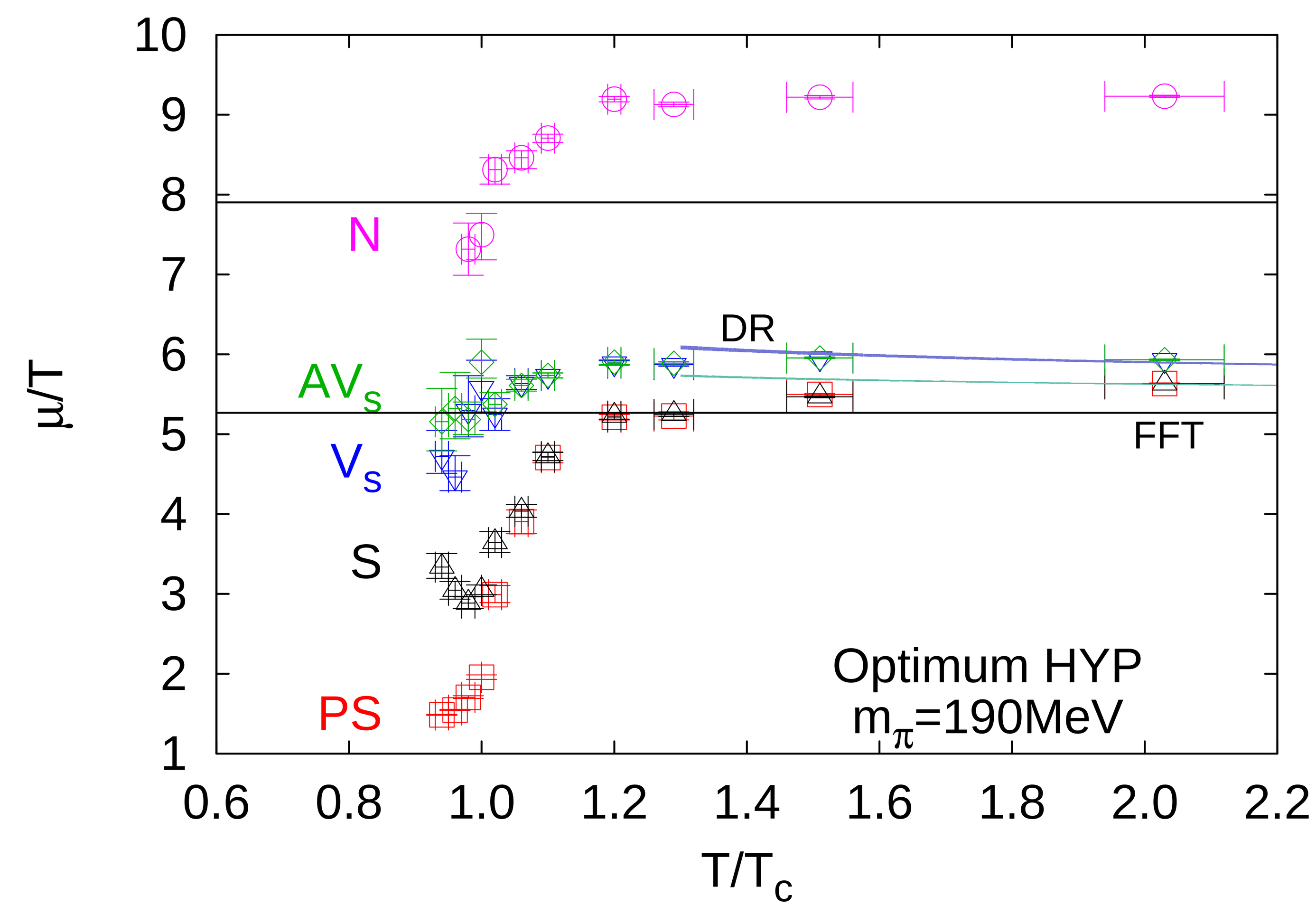
- Suppression of power in X (X is either UV or IR):

$$Q_X = \frac{E_X(\epsilon)}{E_X(0)} \quad \text{with total power in X,} \quad E_X = \sum_{k\in X}|c(k)|^2$$

- Quark sector: Extremal eigenvalues, $\lambda_{\rm min}$ and $\lambda_{\rm max}$, of massive staggered Dirac operator candidates for UV and IR.

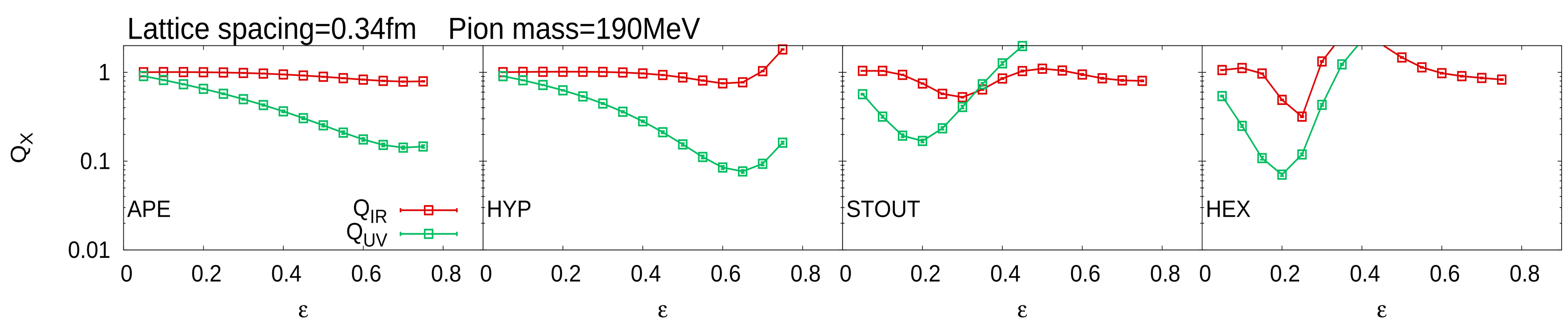
Agreement with weak coupling predictions

Hadronic screening masses were determined with optimum HYP improved staggered valence quark and standard staggered sea quark. For weak coupling predictions (M. Laine *et al.* 2004, W. M. Alberico *et al.* 2007), μ_{FFT} was taken from lattice. This corrects for $\mathcal{O}(a^2)$ artifact which gauge link smearing cannot remove.



Effect of optimized smearing on taste splitting at high T

Tuning ϵ at $T=0$

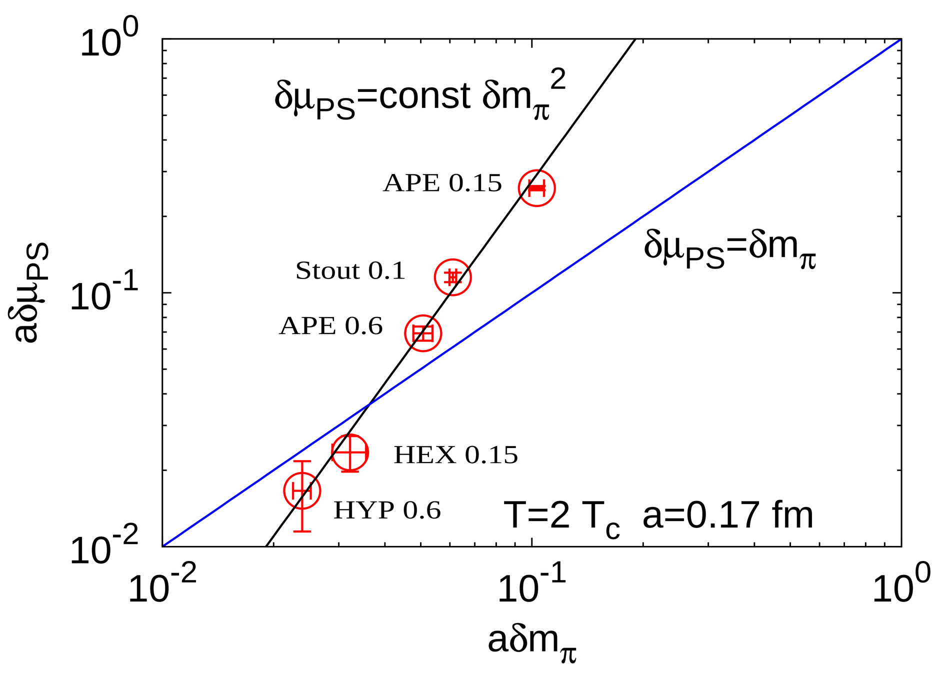


Super-linear improvement at high T

We observe the taste splitting at finite temperature ($\delta\mu_{PS}$) to scale quadratically with improved taste splitting at $T=0$:

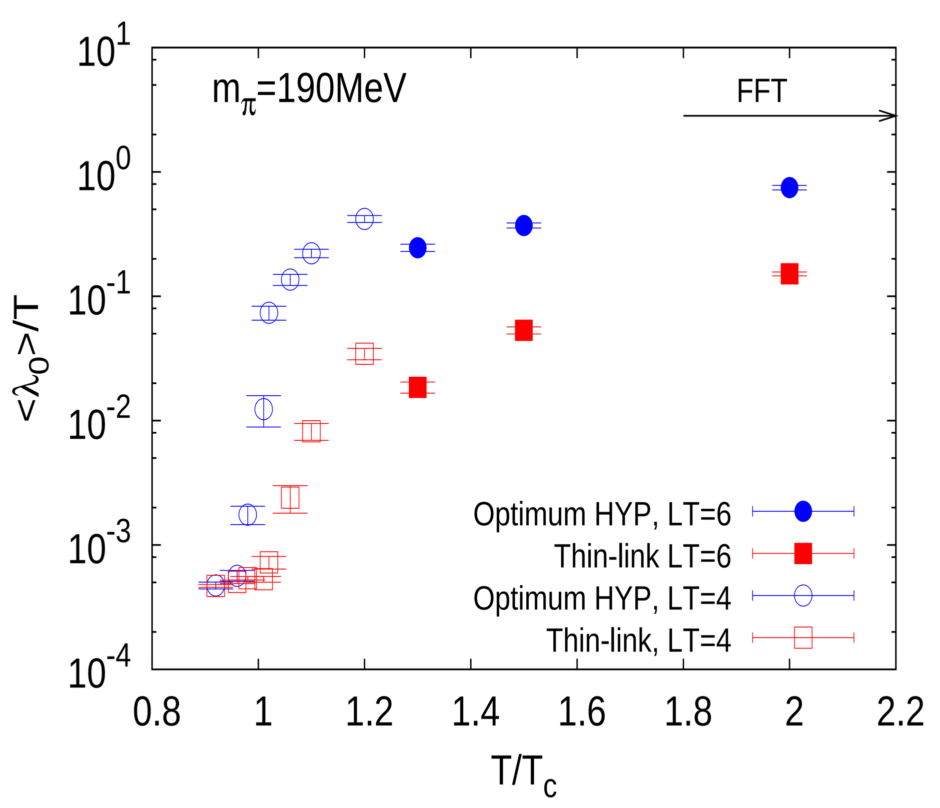
$$\delta\mu_{PS} \propto (\delta m_\pi)^2.$$

Such a scaling could arise due to complete or almost complete restoration of taste symmetry in the chiral limit due to optimal smearing at finite lattice spacing.



Rapid increase in lowest eigenvalue

- λ_0 is the minimum eigenvalue of massless staggered Dirac operator.
- λ_0 increases rapidly between 1 to $1.06T_c$.



Taste symmetry breaking: the crux of the problem

Improving taste symmetry by optimal HYP smearing seems to have a larger effect than by decreasing the lattice spacing. Hence improving $\mathcal{O}(\alpha_S a^2)$ lattice artifact responsible for taste symmetry breaking is important for screening masses.