# scaling study of dynamical smeared-link fermions

(arXiv:0802.2706v1)

Thorsten Kurth, University of Wuppertal

Budapest-Marseille-Wuppertal Collaboration (S. Dürr, Z. Fodor, C. Hölbling, R. Hoffmann, S.D. Katz, S. Krieg, T. Kurth, L. Lellouch, T. Lippert, K.K. Szabo, G. Vulvert)

# outline

- choices of actions
- simulation algorithm
- metastabilities
- scaling study
- summary

# choices of actions

- gauge action: Symanzik improved "thin-link" action
  - $S_G^{Sym} = \beta \left[ \frac{c_0}{3} \sum_{\text{plaq}} \mathrm{Tr}\,\mathrm{Re}\big(1 - U_{\text{plaq}}\big) + \frac{c_1}{3} \sum_{\text{rect}} \mathrm{Tr}\,\mathrm{Re}\big(1 - U_{\text{rect}}\big) \right]$
- fermionic action: clover improved wilson ("smeared-link")
  - $S_F^{SW} = S_F^W[V] - \frac{c_{SW}}{4} \sum_x \sum_{\mu\nu} \psi_x \, \sigma_{\mu\nu} F_{\mu\nu,x}[V] \, \psi_x$
- the parameters are set to their tree-level values
  - $c_{SW} = 1, \quad c_1 = -1/12, \quad c_0 = 1 - 8c_1 = 5/3$

- "smeared-link" refers to stout (EXP)- or HEX-smeared links
  - stout-smearing (ρ=... gstar, Peardon (2004)

$$V^{(n+1)} = e^{\rho S^{(n)}} V^{(n)},$$

$$S^{(n)} = \left(\frac{1}{2} - \frac{\mathrm{ReTr} \ldots}{6}\right) \left(\Gamma^{(n)} V^{(n)\dagger} - V^{(n)} \Gamma^{(n)\dagger}\right);$$

$$\Gamma^{(n)}_{x,\mu} = \sum_{\nu \neq \mu} V^{(n)}_{x,\nu} V^{(n)}_{x+\nu,\mu} V^{(n)\dagger}_{x+\mu,\nu}$$

Why Stout-smearing:
- Widely used
- Shares features with different prescriptions (e.g. Enhaced scaling region)

  - HEX-smearing is achieved by using stout smeared links within the HYP-smearing ... smeared links
    Capitani, Dürr, Hölbling (2007)

HEX-Smearing: locality does not become worse when applying several steps.

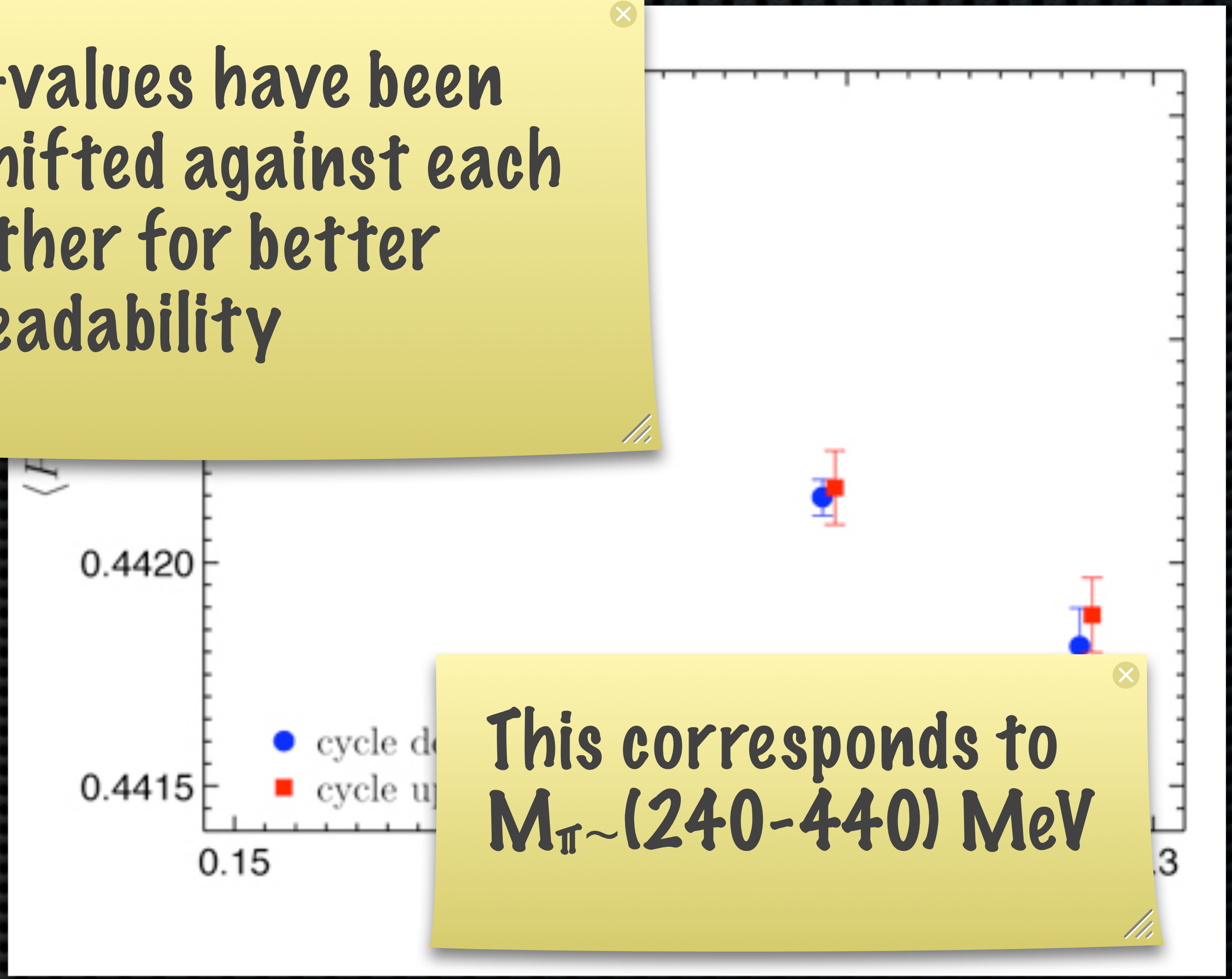
  - 2 steps of HEX-smearing ... parameters $\alpha_1$=0.95, $\alpha_2$=...

# simulation algorithm

- HMC/RHMC integrator with following improvements
  - multiple time-scale integration to reduce computational costs — Sexton, Weingarten (1992)
  - mass preconditioning for reducing fluctuations in the force — Hasenbusch (2001), Urbach (2006)
  - omelyan integrator for improved energy conservation — Omelyan et al. (2003)
- used mixed precision solver for Dirac-inversions in the sea- and valence-sector to speed-up inversions — Giusti et al. (2003)
- we chose $N_f=3$ for easier tuning (RHMC treats third flavour)

# metastabilities

- dynamical simulations with very small quark masses may become unphysical
  Aoki et al., Farchioni et al. (2005)
- problem occurs at coarse lattices and weakens with smearing
- problem is absent in simulations with O(a) improved actions (fermionic and gauge)
- in case this problem is present, it will show up in a hysteresis in the plaquettes thermal cycle




x-values have been shifted against each other for better readability

This corresponds to $M_\pi \sim (240\text{-}440)$ MeV

absence
thermal
fixed stra
and vary
ascendir
(circles,

No washing out of hysteresis: 100 Therms and 200 prods with nmeas=10!

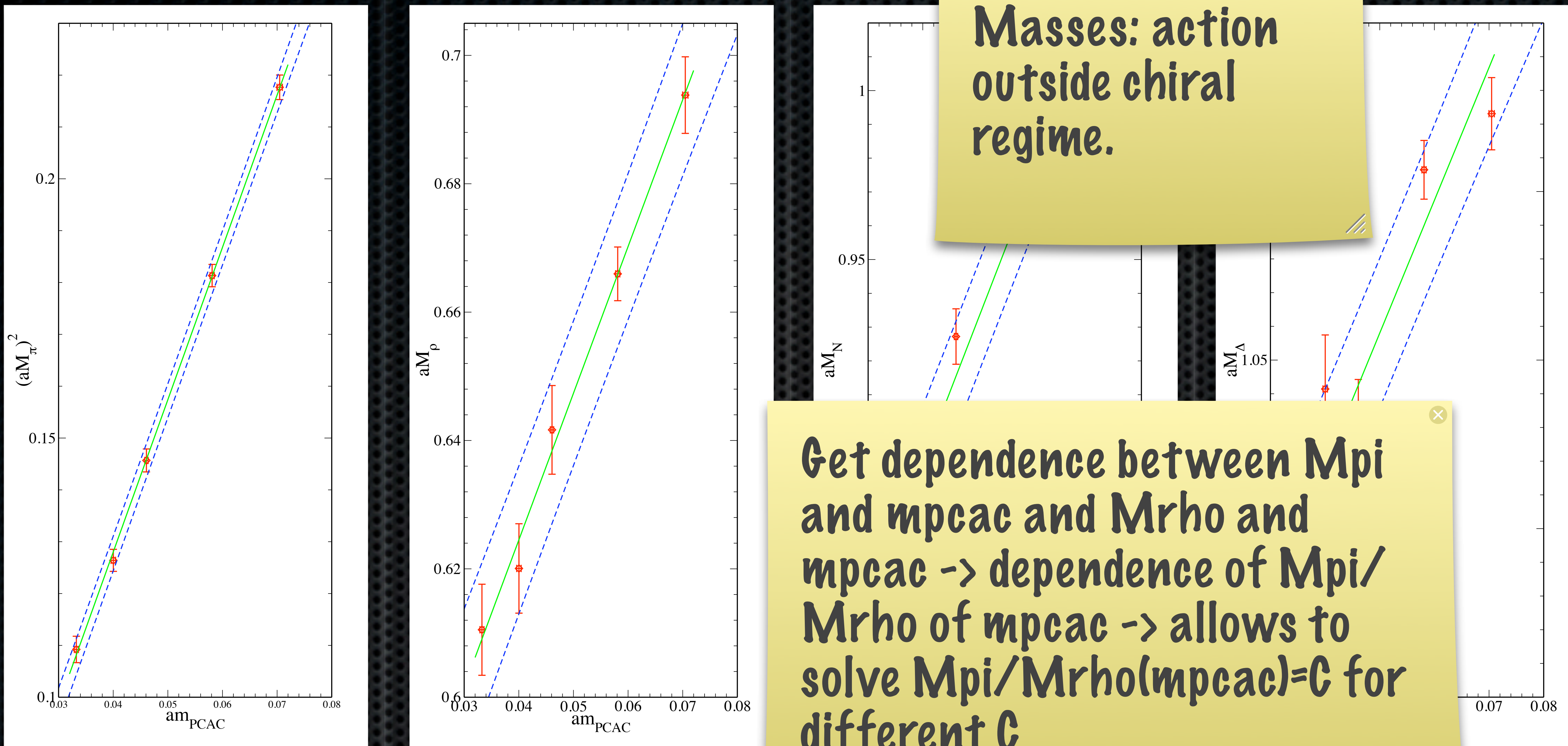
# scaling study

- the scaling runs were performed at 5 different β (from 2.8 up to 3.76) and lattice spaces with L/a varying from 8 to 24, and we chose $N_t$=2L
- for each beta, we generated configs at at least 5 different wilson masses, where we made sure that the simulation stayed in the ($M_\pi L>4$)-regime, so that finite volume effects are negligible
- to deal with the errors, we performed a moving block bootstrap (MBB) analysis with 2000 samples and repeated the whole analysis on each MBB sample
- the integrated autocorrelation time for <P> is between seven and ten trajectories, hence we choose a larger MBB binning for the finer lattices

- generated correlators using Gaussian/Wall or G
- we extracted the PCAC-mass, needed for the
  for every run by averaging over the correspond
  always been very well pronounced
- we extracted the masses for the spin-0 ($M_\pi$) and 1 ($M_\rho$), 1/2 ($M_N$) and 3/2 ($M_\Delta$) particles, using a correlated cosh-/sinh-fit, where the covariance matrix has been estimated using the MBB samples and was chosen to be constant on each MBB sample
- we made sure that no excited states have been fitted
- for each $\beta$, we fitted the extracted masses linea
  interpolated for different LCP with $M_\pi/M_\rho \in \{0.6,$

PCAC mass needed for interpolation -> best scaling properties of masses while quantity itself has the smallest error (systematical and statistical)

Choose rather large masses: enhance possible O(a) discretization effects

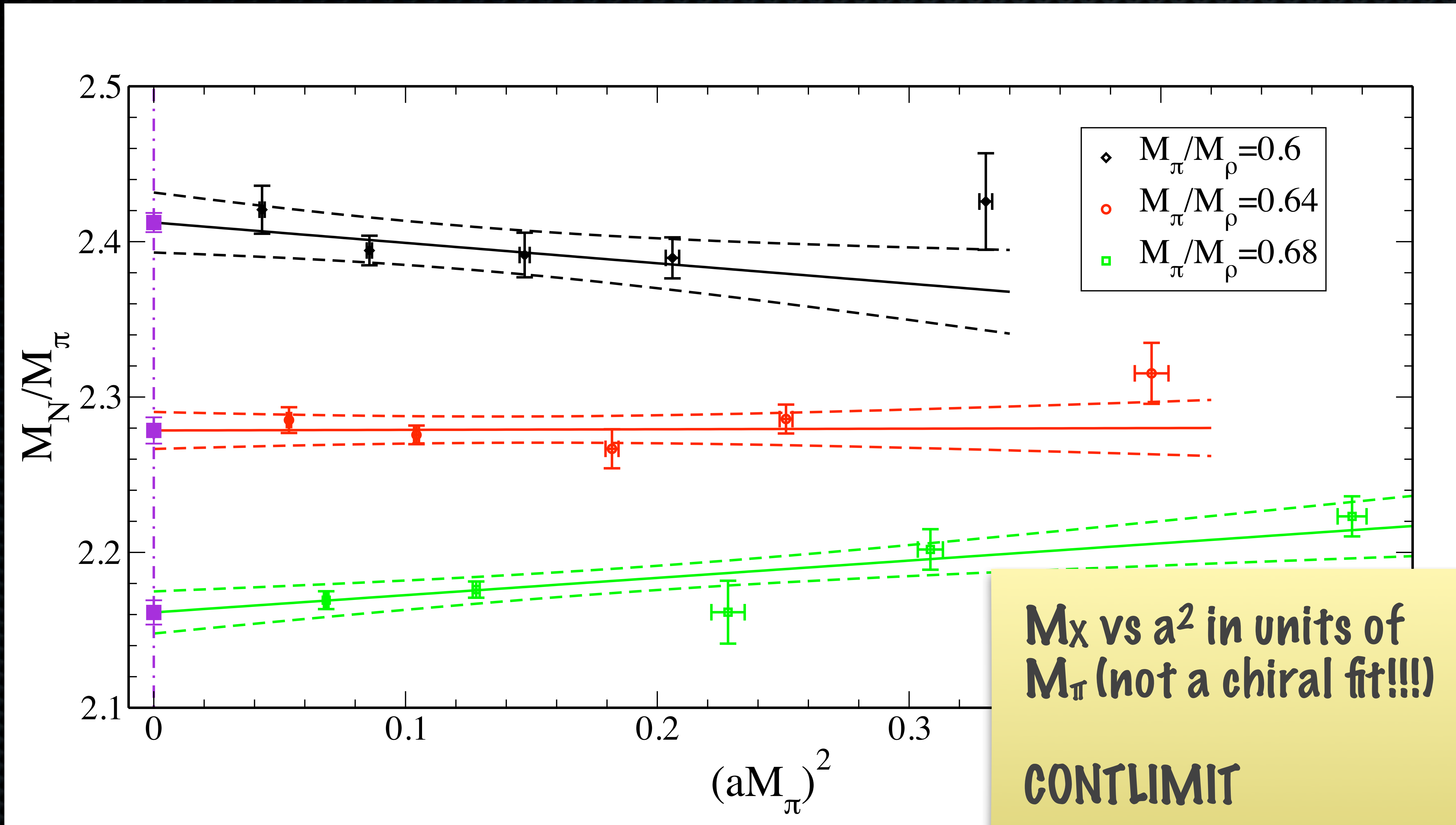



Large PCAC-Masses: action outside chiral regime.

Get dependence between Mpi and mpcac and Mrho and mpcac -> dependence of Mpi/Mrho of mpcac -> allows to solve Mpi/Mrho(mpcac)=C for different C

# mass interpolation (HEX)

linear fits of the spectrum in terms of $m_{PCAC}$ ($\beta$=3.4, L/a=12)

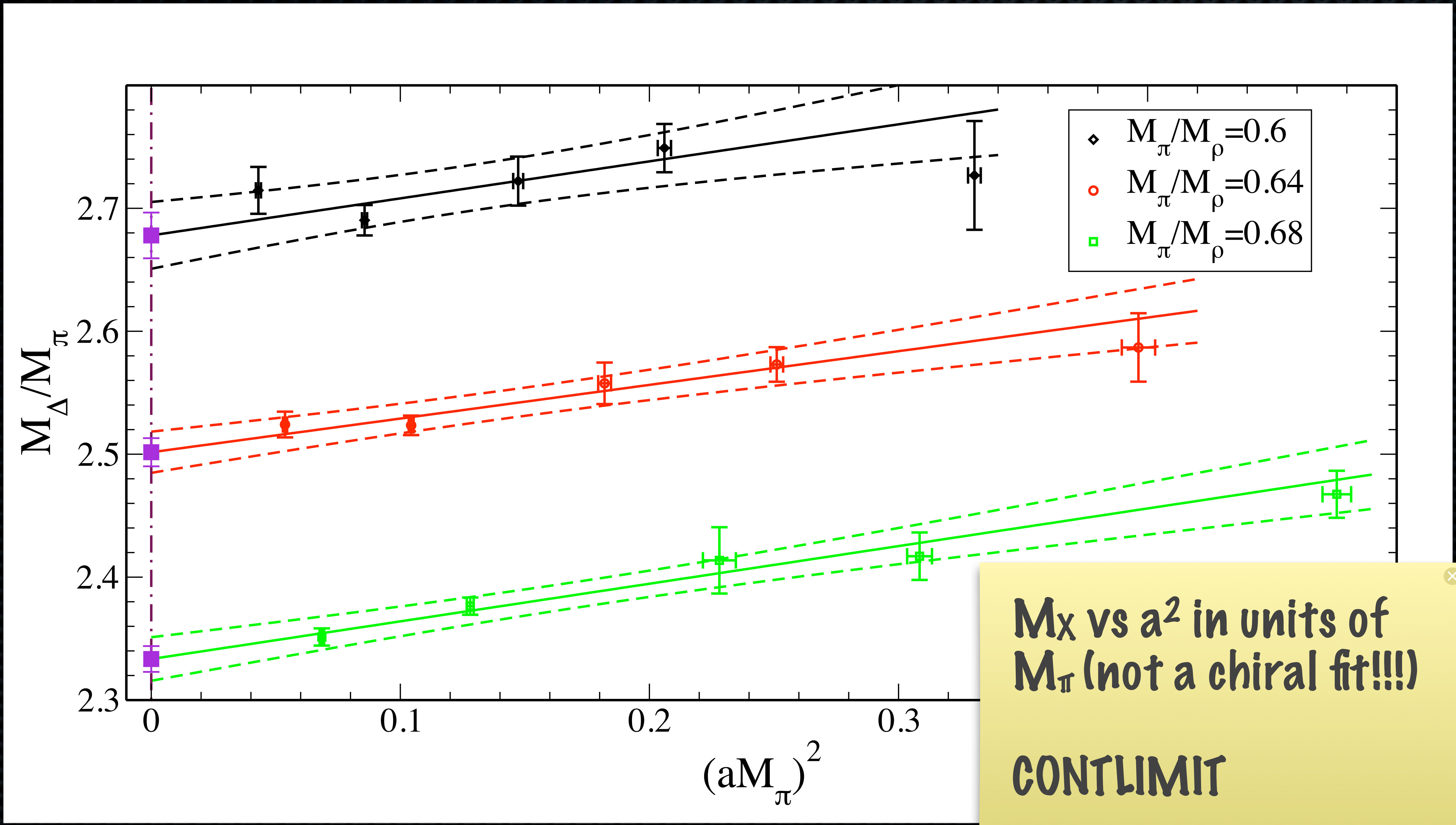



$M_X$ vs $a^2$ in units of $M_\pi$ (not a chiral fit!!!)

CONTLIMIT

# continuum scaling I (HEX)

$M_N$ in terms of $M_\pi$ vs $a^2$ (in units of $M_\pi^{-2}$) for three different LCP

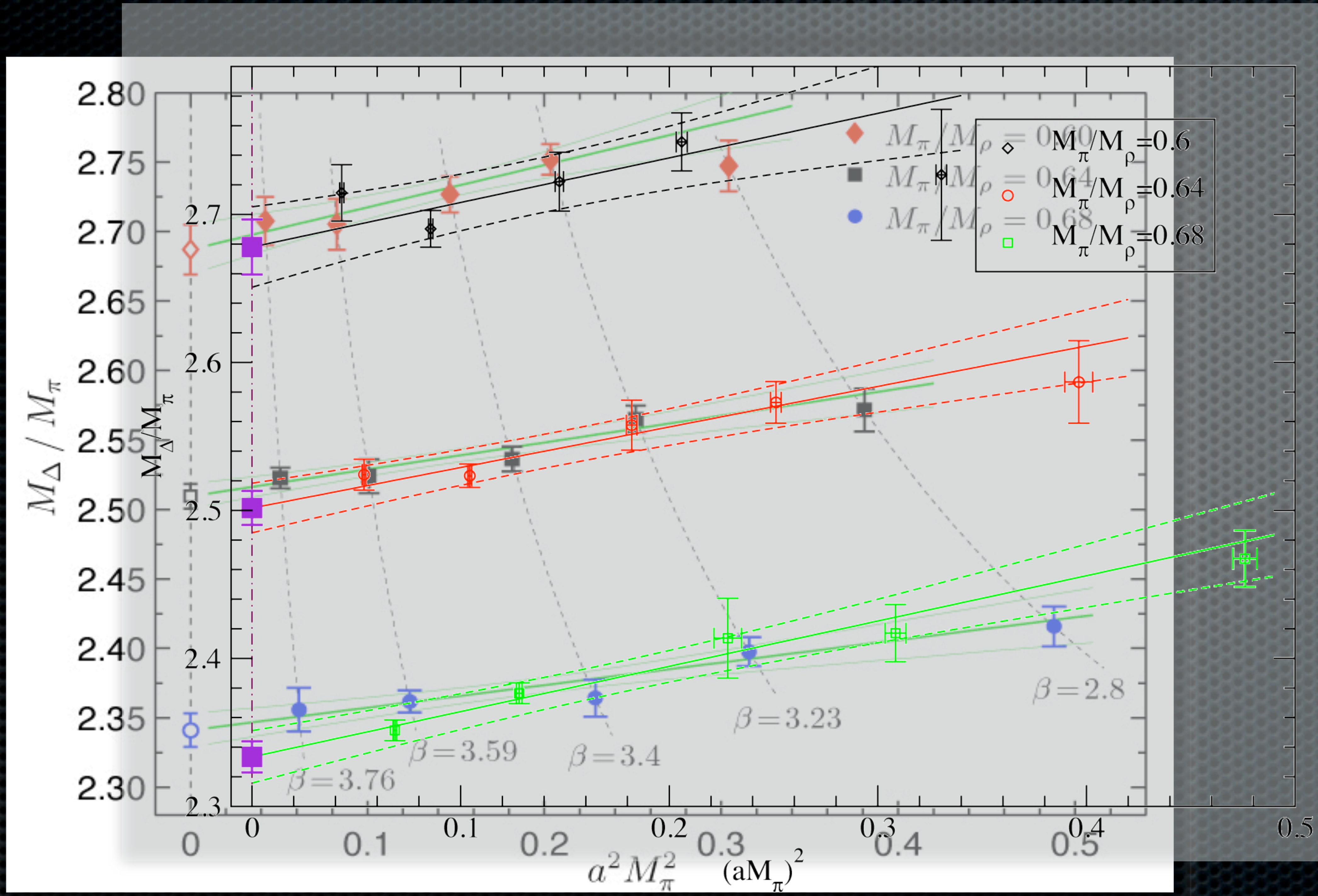



Mx vs $a^2$ in units of $M_\pi$ (not a chiral fit!!!)

CONTLIMIT

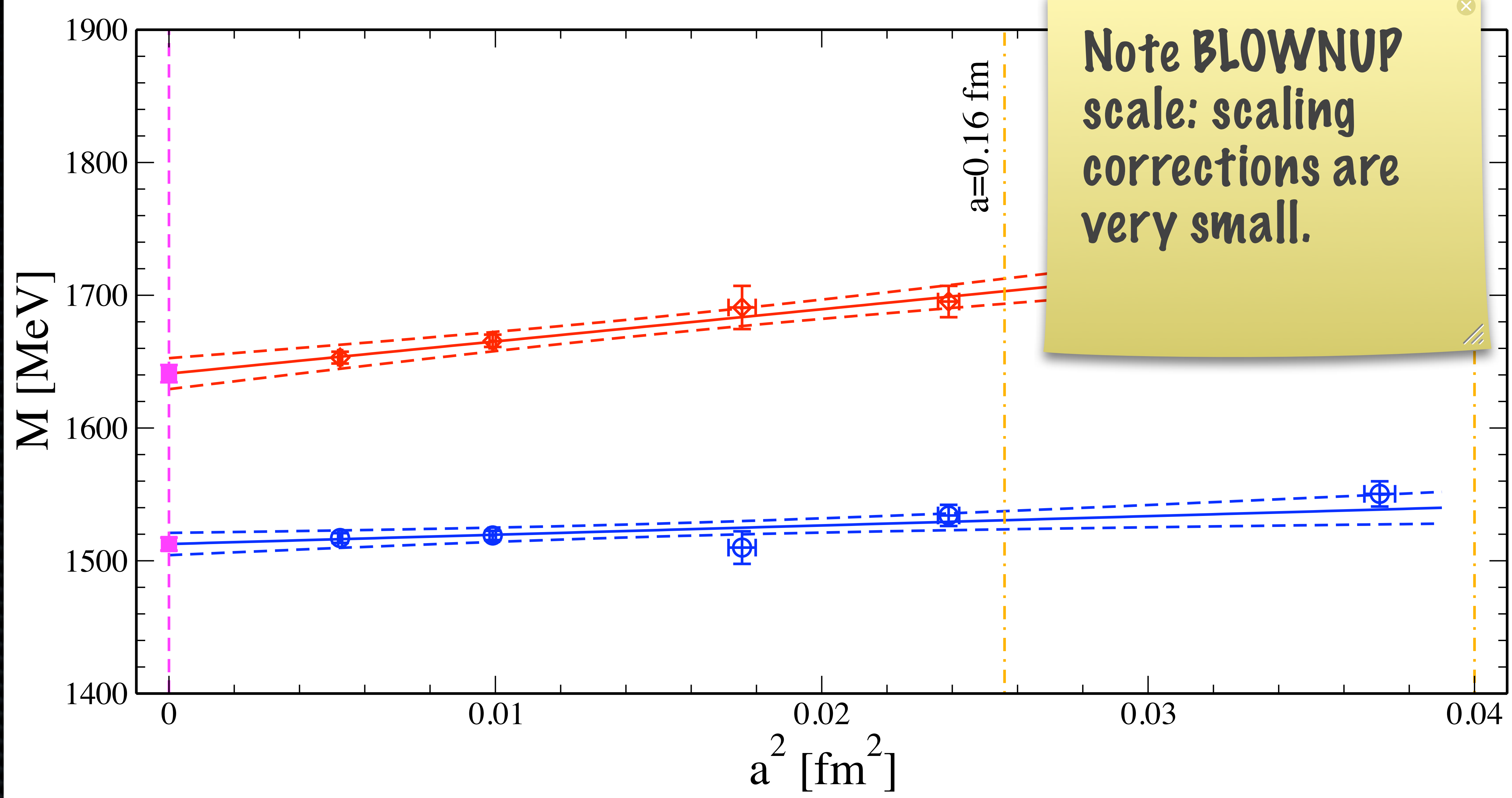
# continuum scaling I (HEX)

$M_\Delta$ in terms of $M_\pi$ vs $a^2$ (in units of $M_\pi^{-2}$) for three different LCP




# continuum scaling II (EXP)

$M_\Delta$ in terms of $M_\pi$ vs $a^2$ (in units of $M_\pi^{-2}$) for three different LCP




Note BLOWNUP scale: scaling corrections are very small.

# continuum scaling III (HEX)

Scaling down to $a^{-1}$<1.3 GeV

scaling of $M_N$ and $M_\Delta$ using

$$M_\pi/M_\rho = \sqrt{2M^2_{K,\text{phys}} - M^2_{\pi,\text{phys}}}/M_{\phi,\text{phys}} \simeq 0.67$$

# summary

- performed a scaling analysis with an efficient stout/HEX-link smeared clover and symanzik improved algorithm at $N_f$=3
- no metastabilities for all lattice sizes and masses
- according to our expectations and experiences with simulations in the quenched case, we found a

  large scaling region up to a≅0.2 fm

  with small scaling corrections