UNIVERSITÄT BONN

Extended Twisted Mass Collaboration

Thoughts for the next five years

Carsten Urbach

Extended Twisted Mass Collaboration (ETMC)

... in case you missed it

$$\text{European} \quad \Rightarrow \quad \text{Extended}$$

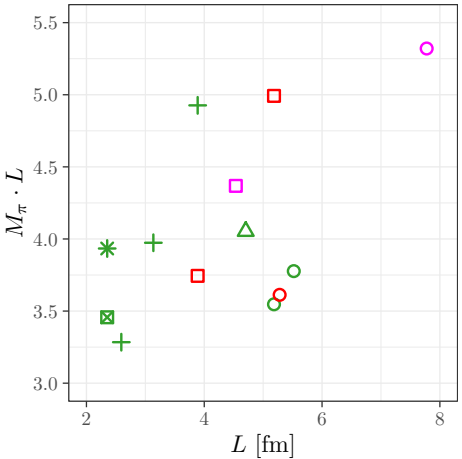
since we include meanwhile colleagues from outside Europe, too:

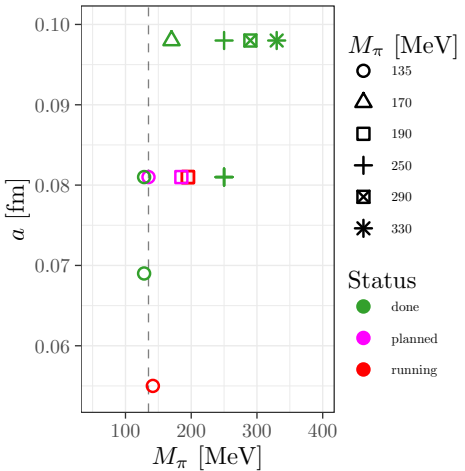
- Cyprus: Nicosia
- France: Grenoble
- Germany: Zeuthen, Jena, Bonn, Frankfurt
- Italy: Rome, Pisa
- Poland: Posnan
- Switzerland: Bern
- USA: Philadelphia
- China: Beijing

ETMC's (latest) Action

- $N_{\mathrm{f}} = 2 + 1 + 1$ flavour lattice QCD
- Wilson twisted mass fermions at maximal twist
- adding the clover term enabled simulations at the physical point
- Iwasaki gauge action
- no smearing, (anti-) periodic boundary conditions
- fixed bare strange and charm quark masses, while light masses are varied

Current Ensemble Landscape





Price Tag

- these ensembles have been generated since 2016 on
  - Marconi
  - Juwels
  - Jureca Booster
  - SuperMUC
  - and local clusters

- corresponding to an investment of about **200 Mcore** hours
  (all gauged to SKL core hours)

- not including tuning and renormalisation runs

ETMC's Physics Programme

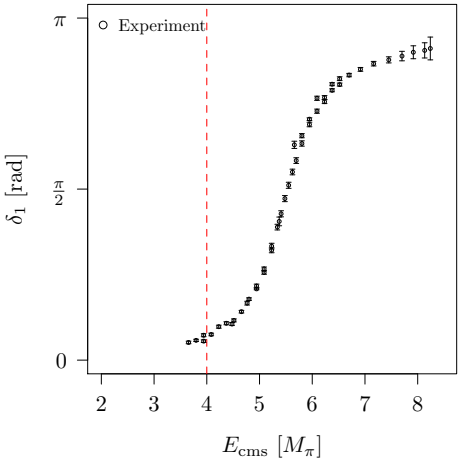
- Hadron Spectroscopy
- Hadron Structure
  - form factors
  - traditional meson and baryon moments of PDFs
  - Quasi-PDFs
- Hadron-Hadron interactions
  - two particles (meson-meson, meson-baryon, baryon-baryon)
  - three particles
- Flavour physics
  - Semi-leptonic decays

Physics Driven Challenges

- scale setting to sub-percent statistical precision
  - requires depending on scale-setting quantity more ensembles / higher statistics / larger volumes
- estimating disconnected contributions
  - likely requires much longer ensembles than available today
- taming excited state contaminations
- estimating isospin-breaking and QED effects (RM123 method)
  - disconnected contributions

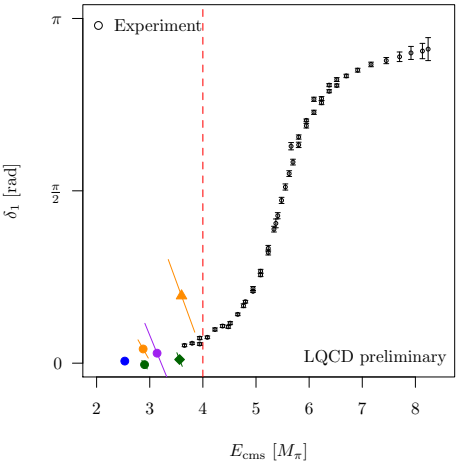
Example: ρ-meson properties at $\mathrm{M}_\pi^{\mathrm{phys}}$

- consider Lüscher method at M_π^{phys}
- inelastic threshold at $E_{\mathrm{cm}} = 4M_\pi$
- below threshold only little variation in δ_1
  $\delta_1 \approx \pi/8$ at $E_{\mathrm{cm}} = 4M_\pi$
- only (very) small energy shifts values below threshold
- need as many points as possible below $4M_\pi$
- with high statistical accuracy



Example: ρ-meson properties at $\mathrm{M}_\pi^{\mathrm{phys}}$

- consider Lüscher method at M_π^{phys}
- inelastic threshold at $E_{\mathrm{cm}} = 4M_\pi$
- below threshold only little variation in δ_1
  $\delta_1 \approx \pi/8$ at $E_{\mathrm{cm}} = 4M_\pi$
- only (very) small energy shifts values below threshold
- need as many points as possible below $4M_\pi$
- with high statistical accuracy



Example: ρ-meson properties at $\mathrm{M}_\pi^{\mathrm{phys}}$

- slope of δ_1 vs E_{cm} below threshold ≈ 0.1
- x-errors roughly equal to y-errors
- need absolute errors on E_{cm}/M_π roughly equal 0.01 to be competitive with experiment (below inelastic threshold)

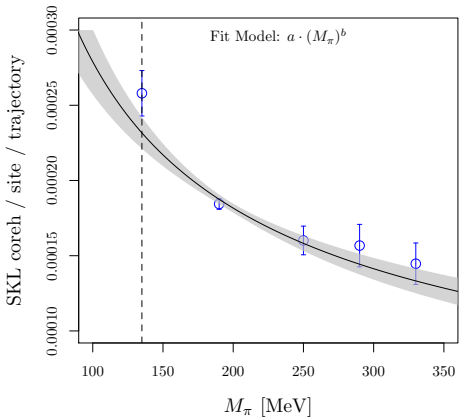
$\Rightarrow$ translates into sub-percent precision for aE_{cm}

- first center-of-mass point below threshold
  - at $L/a \approx 64$ for $a = 0.09$ $\qquad (L \approx 6\ \mathrm{fm})$
  - at $L/a \approx 82$ for $a = 0.07$
  - at $L/a \approx 112$ for $a = 0.05$

  which means only $\mathcal{O}(10)$ points below threshold

Empirical Cost Model Gauge Field Generation

- experience from various machines: SuperMUC, Juwels, Jureca booster, smaller clusters
- Hybrid Monte Carlo with Hasenbusch preconditioning
- DDαAMG solver for light flavours
- mixed QPhiX (multi-shift) CG and DDαAMG for heavy flavours
- rational approximation in the heavy sector

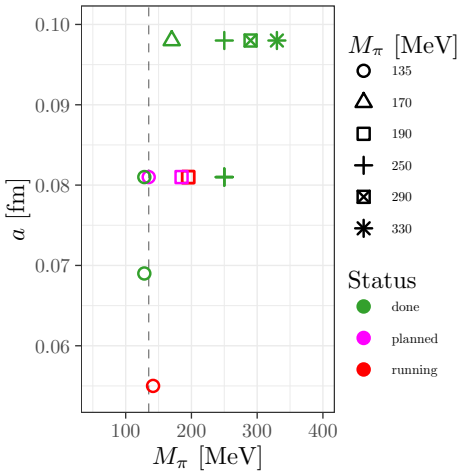


Resource Estimates Gauge Generation (Short Term)

- run planned ensembles
- including a $80^3 \times 160$ ensemble @M_π^{phys}

$\Rightarrow$ control finite volume effects

- fill up with ensembles at larger than physical pion masses
  better controlled continuum and chiral limit
- this will require about 200 Mcore h (SKL)



Resource Estimates Gauge Generation (Longer Term)

Different possibilities / ideas (strategy not yet decided)

- increase statistics @$M_\pi^{\rm phys}$, fixed physical volume (50k trajectories) for three lattice spacings

$\Rightarrow$ about 13000 Mcore h (SKL)

- three volumes @$M_\pi^{\rm phys}$ at $a = 0.07$ fm, 5, 7 and 9 fm (50k trajectories)

$\Rightarrow$ about 7700 Mcore h (SKL)

- large volume at $a = 0.07$ fm, 12 fm (5k trajectories)

$\Rightarrow$ about 2000 Mcore h (SKL)

Using GPU machines here, would drastically change the picture

BSM (idea of Frezzotti/Rossi

Alternative mass generation mechanism

- simulations with SU(3) gauge fields, fermions and scalars
- extended quenched study: 2 Mcore h (SKL)
- followed by dynamical study: 120 Mcore h (SKL)

Costs for Measurements

Measurement costs are much harder to estimate

- depend on particular project
- can be much better run on smaller size systems
- already efficiently running on GPUs

But can easily become of similar amount as gauge generation

Personal Questions / Thoughts

- why would we want community access?
  (if not externally imposed on us)
- to maintain our level of recources (speak with one voice)
- obvious answer: if we get more resources (is that likely?)
- or if we get the same resources with less effort
- less obvious: if we start collaborating more / at all
  (e.g. could restrict to two actions in Europe)
- a community effort for code development would be very much needed
  - upcoming machines will all be GPU based
  - the upcoming exascale machines in Europe will require special tuning