Baryon spectroscopy with $N_F = 2 + 1 + 1$ twisted mass fermions

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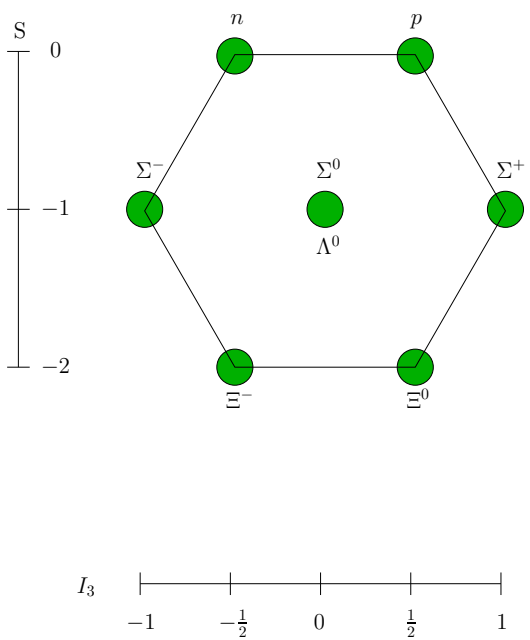
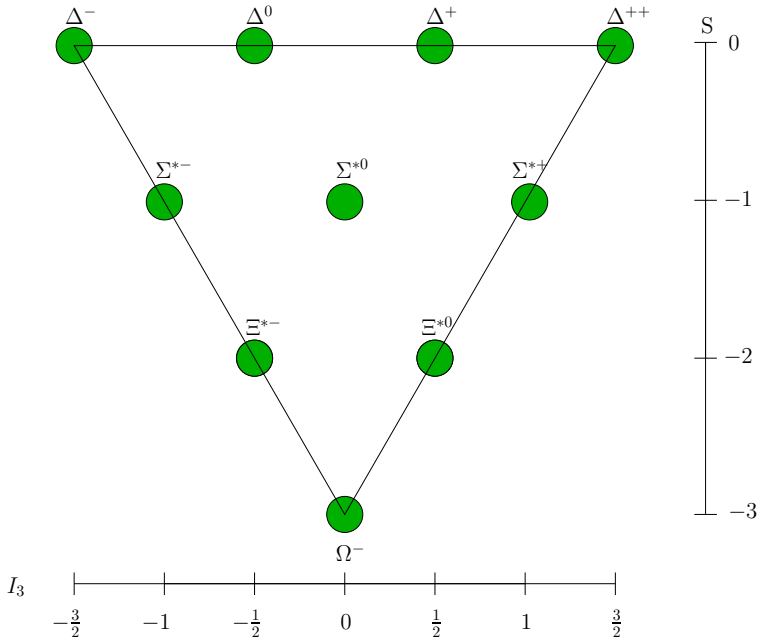
Outline

Lattice setup $N_F = 2 + 1 + 1$

$N_f = 2 + 1 + 1$ gauge ensembles

- 3 lattice spacings: $0.055 - 0.09$ fm ($\beta = 1.90,\ 1.95$ and 2.10)
- $270 \lesssim m_{\rm PS} \lesssim 600$ MeV
- $L > 2$ fm
- $m_\pi L > 3$





Lattice techniques

General remarks

- Same interpolating field than the one use in our $N_F = 2$ study
- Mass are extracted using effective masses.
- Smearing : Gaussian and APE

Strange sector

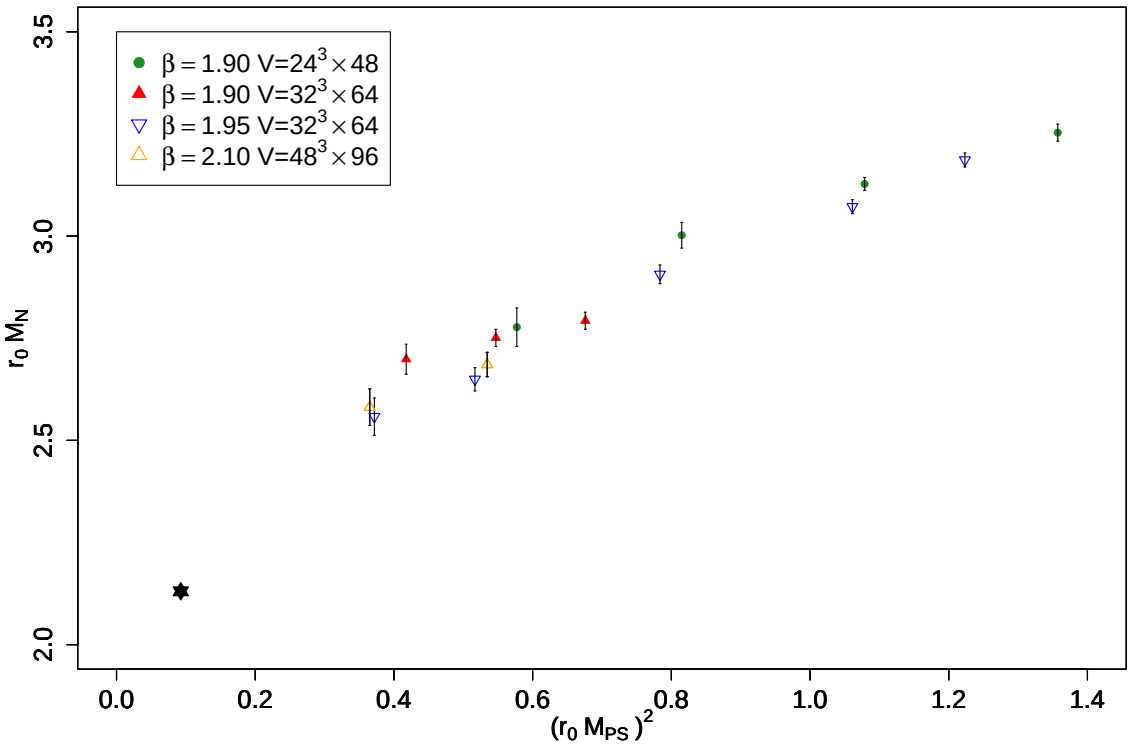
- Non-generate maximally twisted mass quarks :

$$S^{\text{heavy}}[\bar{\chi}, \chi] = a^4 \sum_x \bar{\chi}(x) \Big[\gamma_\mu \tilde{\nabla}_\mu + m_0 - r \frac{a}{2} \nabla^*_\mu \nabla_\mu + i \mu_\sigma \gamma_5 \tau_1 + \mu_\delta \tau_3 \Big] \chi(x)$$

- Goal : study baryon spectrum in the mixed action setup and in the unitary setup
- Mixed action setup : Osterwalder-Seiler strange quark matched on the unitary kaon mass at each light quark mass :

$$m_K^{\text{OS}}(a\mu_l, a\mu_s, \beta) = m_K^{\text{unitary}}(a\mu_l, a\mu_\sigma, a\mu_\delta)$$

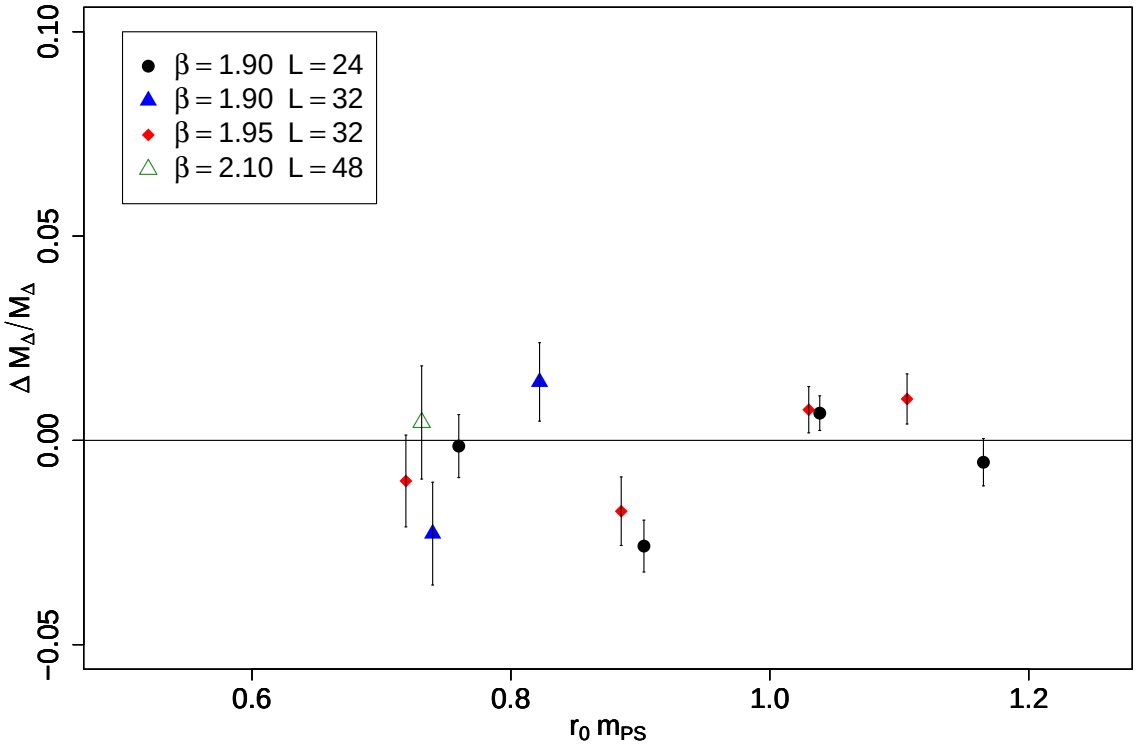
Light baryon masses with $N_F = 2 + 1 + 1$



Nucleon

- 3 lattice spacings
- several volumes included at $\beta = 1.90$
- Physical scale has been set using f_π

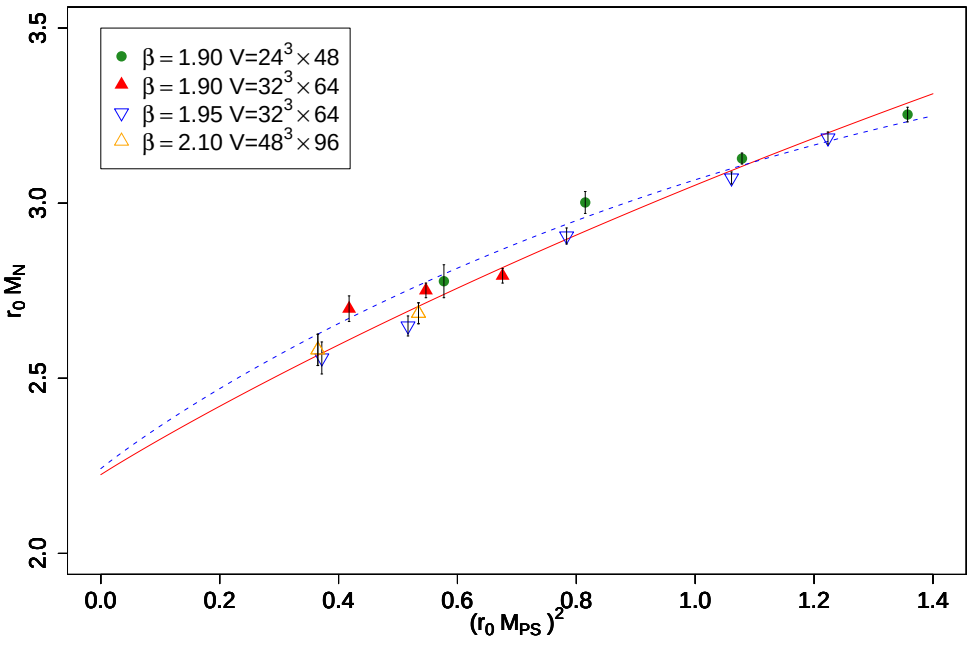
Isospin breaking



$O(a^2)$ effect

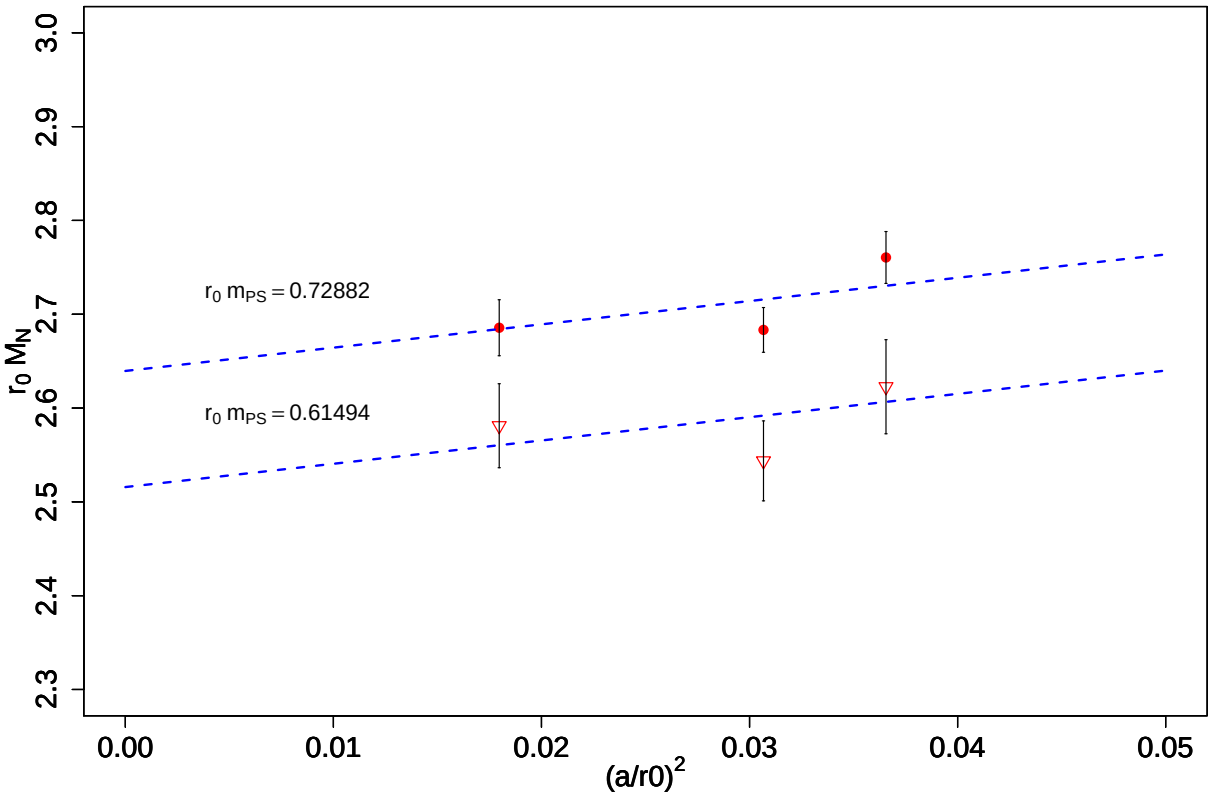
- Relative difference of mass between Δ^{++} and Δ^{+} *i.e* : $\Delta M_\Delta / M_\Delta^{\text{average}}$
- Pion mass greater than 300 MeV
- Isospin breaking $\leq 2\%$ – comparable to $N_F = 2$ case

Combined fit



- Combined Polynomial fit of the form: $m_N = m_N^0 + Am_\pi^2 + Bm_\pi^3 + C(a/r_0)^2$, $(\chi^2/ndof = 0.6)$
- red line : corresponding continuum extrapolation of $N_F = 2 + 1 + 1$ data
- Combined fit on $N_F = 2$ results : $\chi^2/ndof = 1.6$
- blue dotted line : corresponding continuum extrapolation of $N_F = 2 + 1 + 1$ data

Discretization effects



$O(a^2)$ effects

- Continuum extrapolation at two fixed reference pion mass using the best fit parameter C
- Small artefacts in the nucleon sector

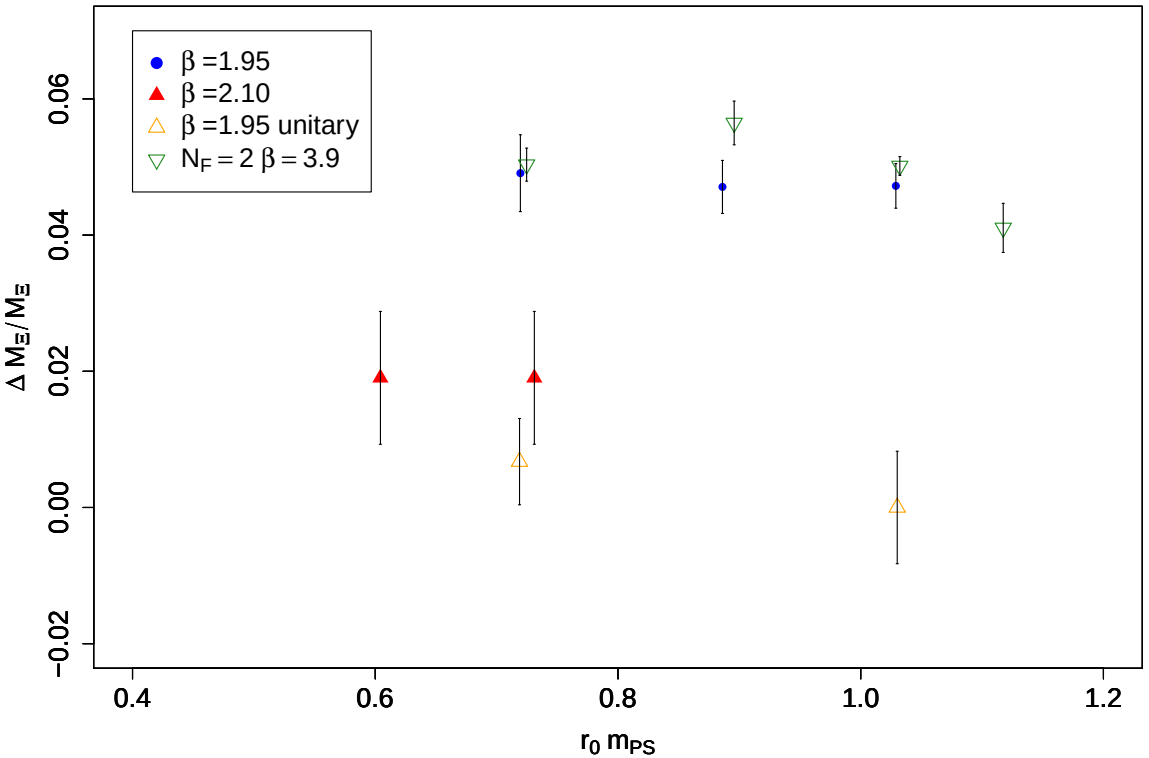
Mixed action setup

- Preleminary matching of kaon mass in the unitary and mixed action setup at $\beta = 1.95$ and 2.1
- Isospin breaking inside the Ξ isospin multiplets ?
- Use $N_F = 2$ partially quenched results as a benchmark to perform a qualitative comparison

(C. Alexandrou,2009)

- First preleminary comparison between mixed and unitary setup

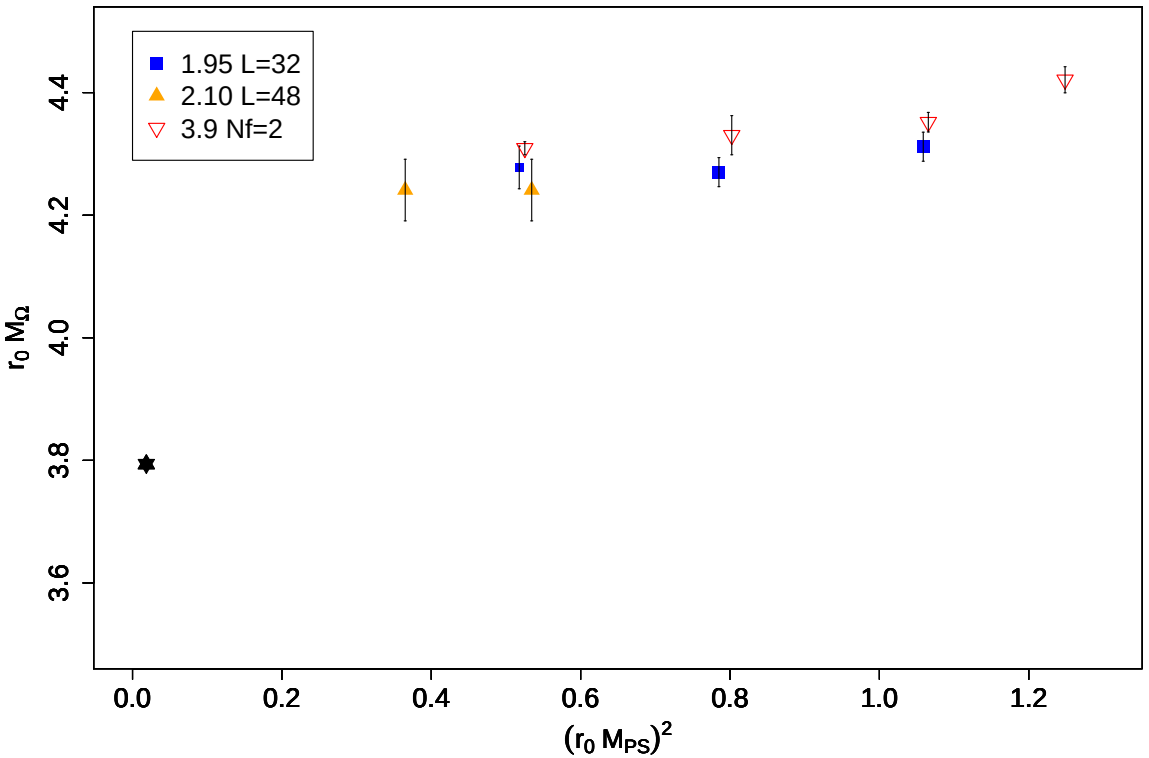
Isospin breaking



$O(a^2)$ effects

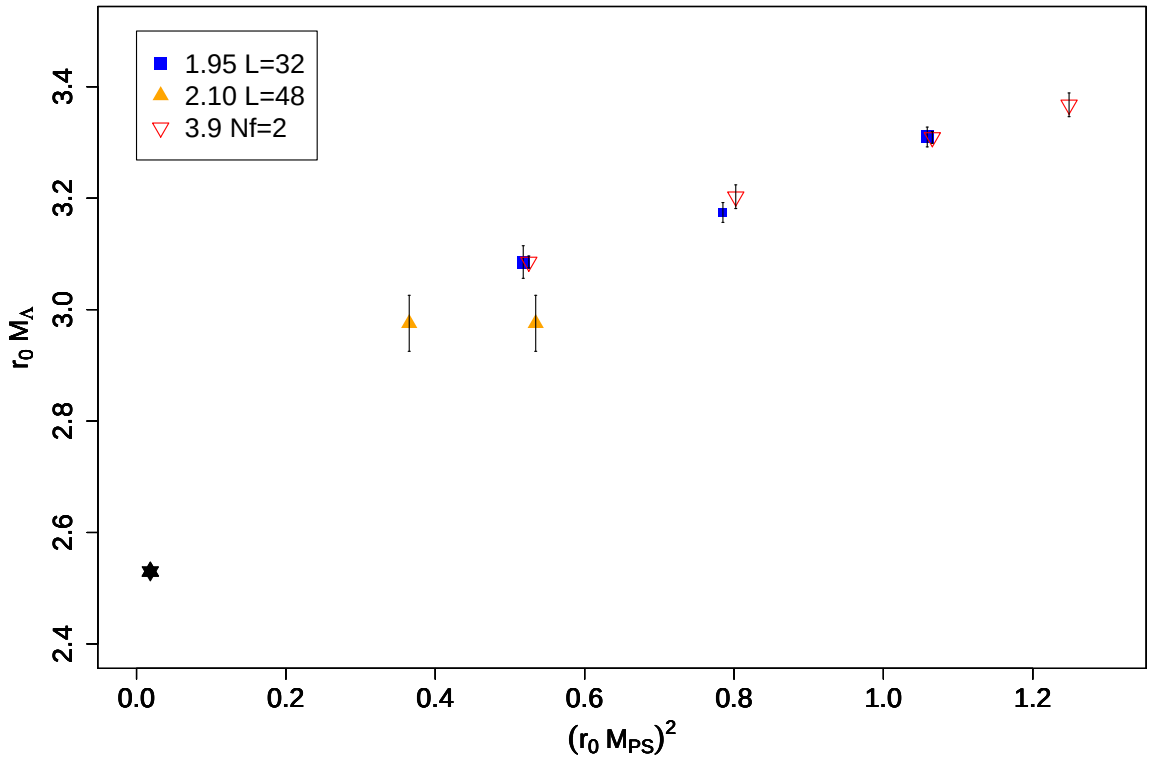
- Isospin breaking in the Ξ sector below 6%
- Spliting decreases with a ($\sim$ 2% at $\beta = 2.1$)
- $\longrightarrow$ very close to the $N_F = 2$ situation where the difference is at most of 7%

Chiral behavior : Ω



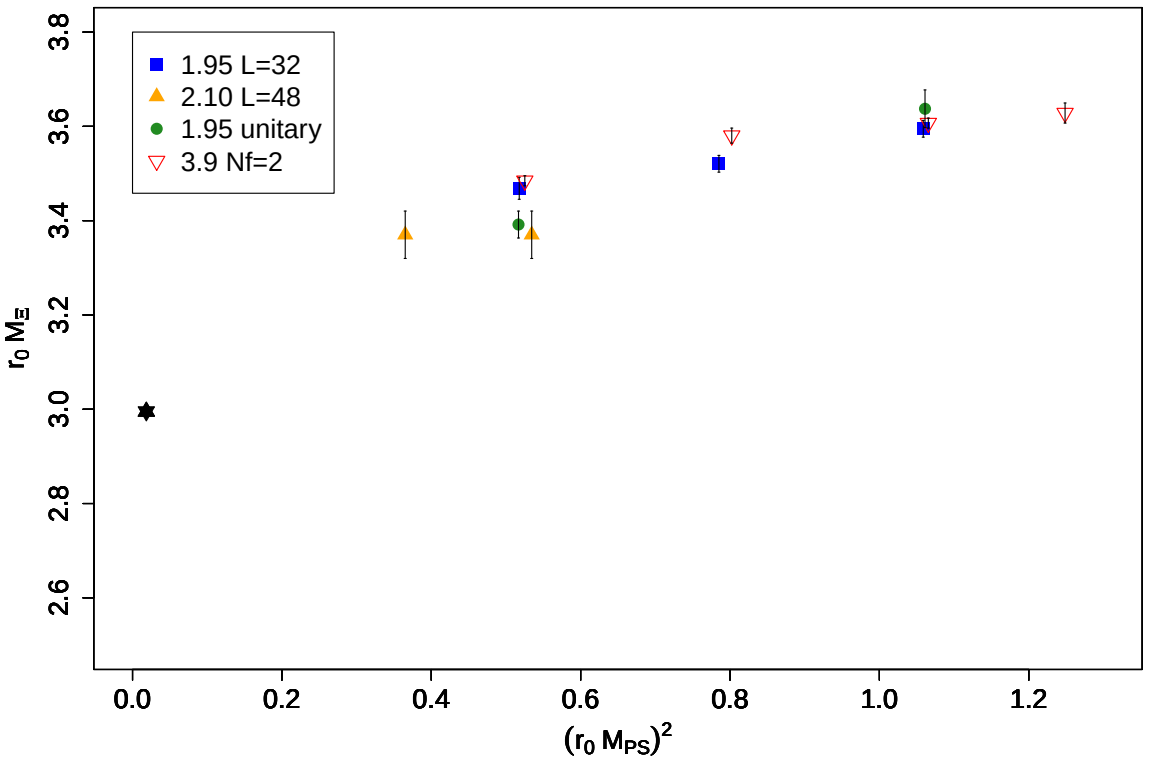
- Small dependence in the light quark mass
- $\beta = 2.1$ and $\beta = 1.95$ results in agreement
- close to the $N_F = 2$ results

Chiral behavior Λ



- Results compatible with $N_F = 2$

Chiral behavior Ξ



- First unitary measurement shows at $\beta = 1.95$ $a\mu_l = 0.0035$ and 0.0075 are in agreement mixed action results
- Nice coherence of the various setup

Conclusion

Light sector

- Contrary to the pion sector, isospin breaking in the Δ masses is of the same order of magnitude than in the $N_F = 2$ case
- Combined polynomial fit of $N_F = 2 + 1 + 1$ data have been performed performed and is compatible with the corresponding fit obtained in two flavours case
- Artefacts in the nucleon sector are compatible with 0

Strange sector

- Isospin breaking not larger than in the $N_F = 2$ case
- Chiral behavior of strange baryons is comparable to the $N_F = 2$ results
- Need a more detailed study of the kaon mass dependence to be able to have quantitative statements.