Smoothing Properties of Wilson Flow for Orientifold Theories

M. Della Morte, **B. Jäger,** S. Martins,
T. Tsang and F. Sannino
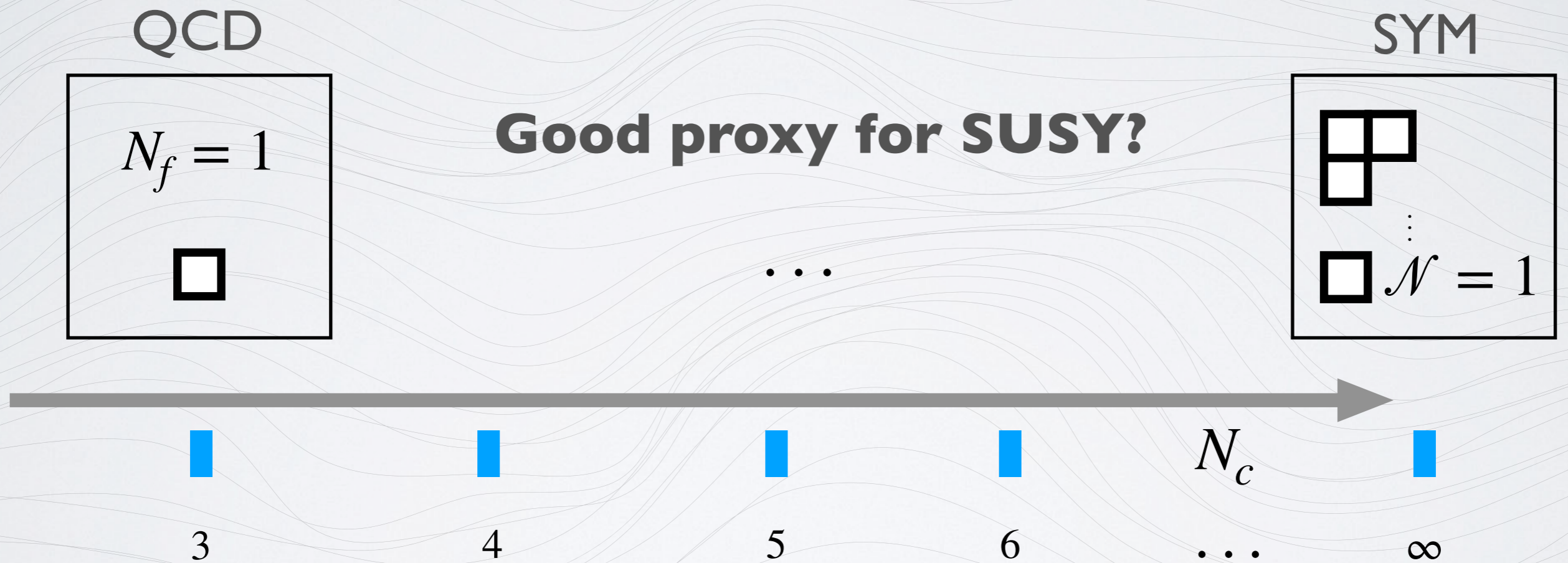
SDU

UNIVERSITY OF
SOUTHERN DENMARK

ℏ QUANTUM
THEORY CENTER

D·IAS

Motivation

- Simulate SUSY without the need to simulate SUSY
- Two-index anti-symmetric fermions

QCD

SYM

$N_f = 1$

Good proxy for SUSY?

$\mathcal{N} = 1$

$\cdots$

N_c

3   4   5   6 $\cdots$ ∞

previous work
Corrigan & Ramond, 1979
hep-th/0309252   hep-th/0403071
hep-th/0603045   hep-th/0609187
hep-lat/0810.0161

Study SUSY with $N_f = 1$ Lattices

- Simulate SUSY without the need to simulate SUSY
- Two-index anti-symmetric fermions

  - Study spectrum and compare to EFT

$$\frac{M_{PS}}{M_S} = 1 - \frac{22}{9N_C} - \frac{4}{9}\beta + \mathcal{O}(1/N_C^2)$$
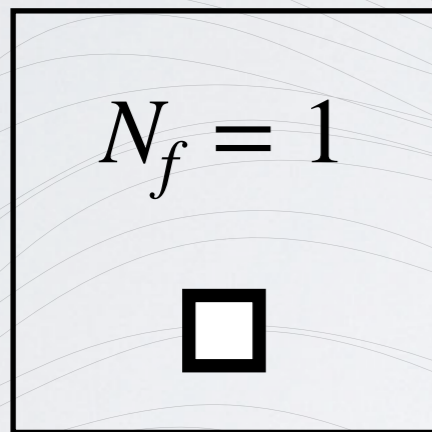
  - @ Lattice: Compute masses and check the ratio

Study SUSY with $N_f = 1$ Lattices

- Simulate SUSY without the need to simulate SUSY
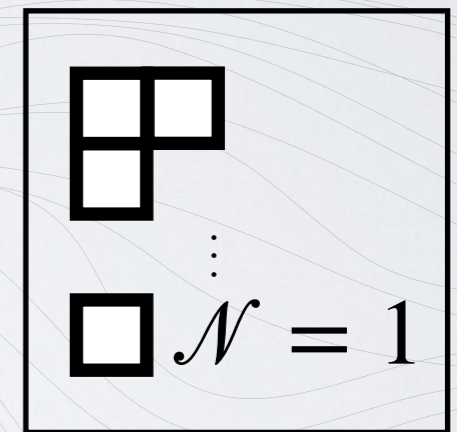- Two-index anti-symmetric fermions

QCD

SYM

$N_f = 1$

Good proxy for SUSY?

$\mathcal{N} = 1$

. . .

N_c

3   4   5   6   . . . ∞

✓

Next

previous work
Corrigan & Ramond, 1979
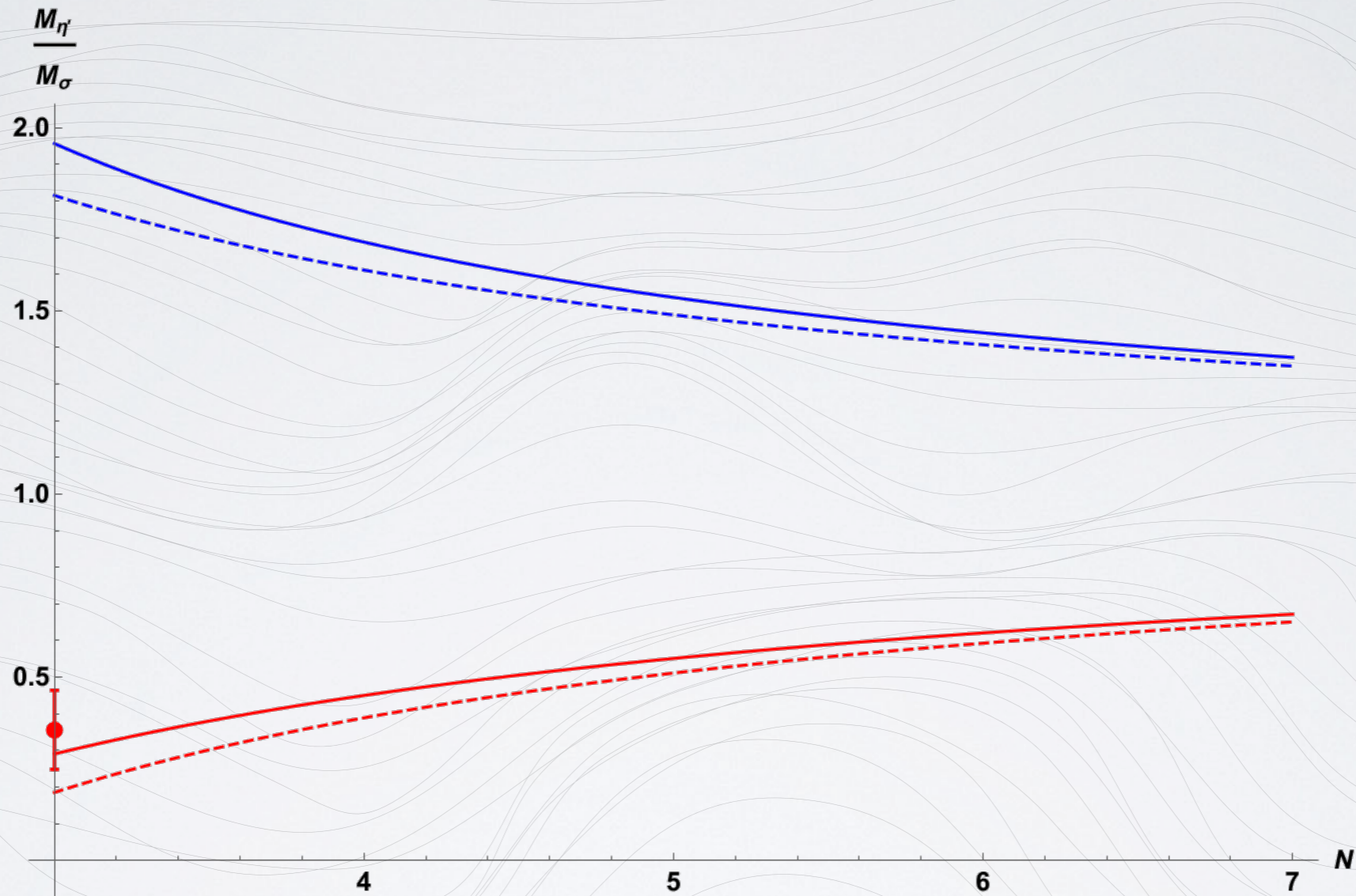hep-th/0309252   hep-th/0403071
hep-th/0603045   hep-th/0609187
hep-lat/0810.0161

**Phys.Rev.D 107 (2023) 11
hep-lat/2302.10514**

Comparison of EFT and Lattice

Sannino
hep-th/2402.05850

- Lattice with 2σ

- Suggested expansion: $\dfrac{M_{PS}}{M_S} = \dfrac{1 - 2/N_C}{1 + \frac{4}{9N_C}}$

Going to larger N_C

- **Our setup** ($N_C = 4, 5, 6$)

  - Gauge: Symanzik improved gauge action
  - Fermion: $\mathcal{O}(a)$ improved Wilson fermions ($c_{sw} = 1$)
  - Aim for $a \sim 0.1$ fm

- **Runs:**

  - Code: **HiRep** on LUMI-G   (Thanks to Sofie Martins!!)
  - 6 Masses and volumes ($m_\pi L > 4$)
  - Going from $N_C = 3$ to $N_C = 4$ scales roughly by factor 3
 - Larger N_C slower and slower

While we wait …

- **Interesting side project**

  - Non-integer topological charge for two-index sym.
  - Studied for $N_C = 3$ by Fodor et.al in JHEP 08 (2009) 084
  - Relevant for SUSY to obtain a non-zero gluino condensate
  - Fractional charges observed for coarse lattices only

- **Expand to larger N_C**

  - Just measure the topological charge for large N_C ensembles
  - Check if fractional charges appear ($N_C > 3$)
  - Flow long enough to have a smooth configuration

- **Generated 5 ensembles (physical vol. and pion matched)**

Wilson flow

N4L12k15770b71 - Config 193

- What is happening to the topological charge?
- For reference: $t_0/a^2 = 0.9$

8

Wilson flow

N4L12k15770b71 - Config 244
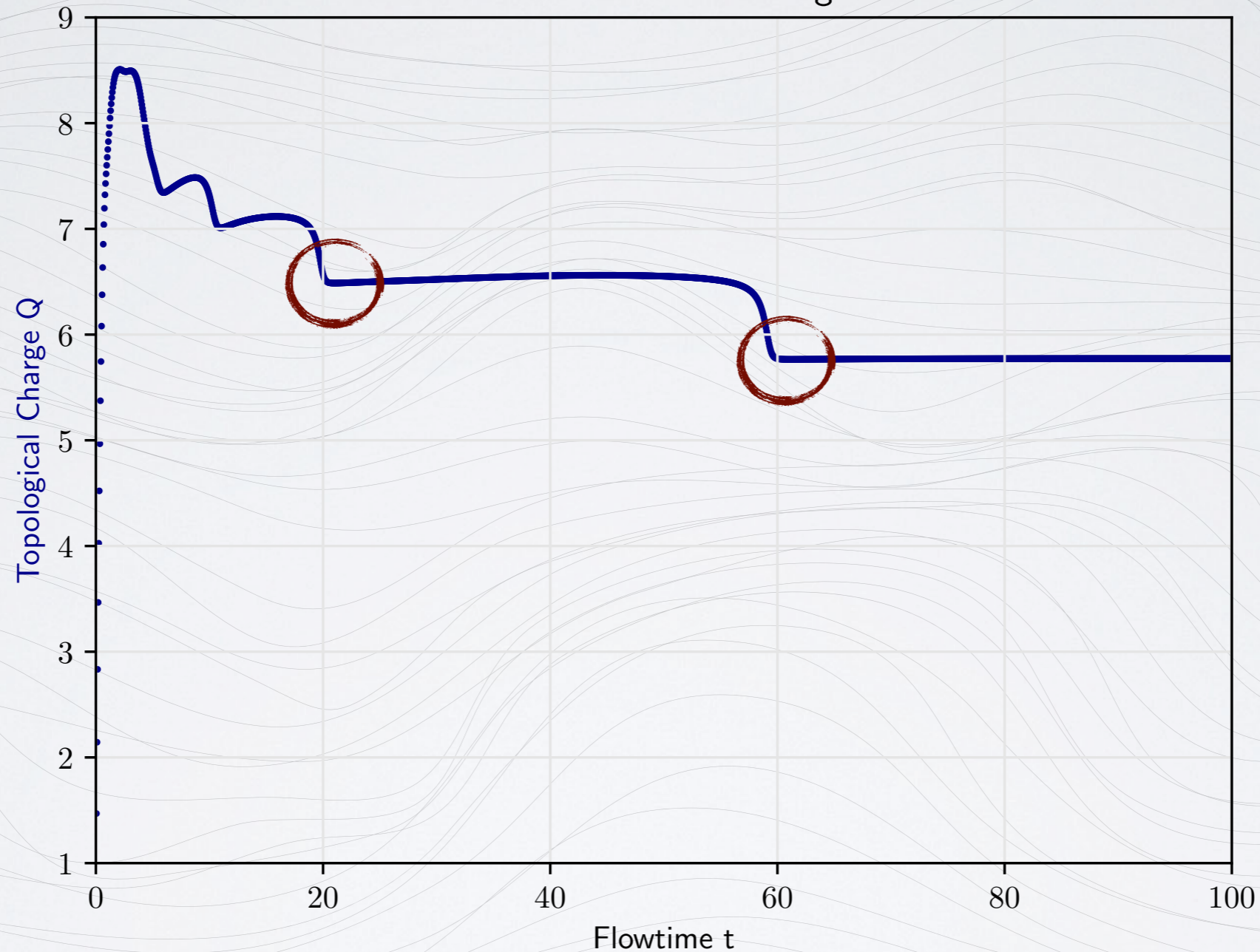
- What is happening to the topological charge?
- For reference: $t_0/a^2 = 0.9$
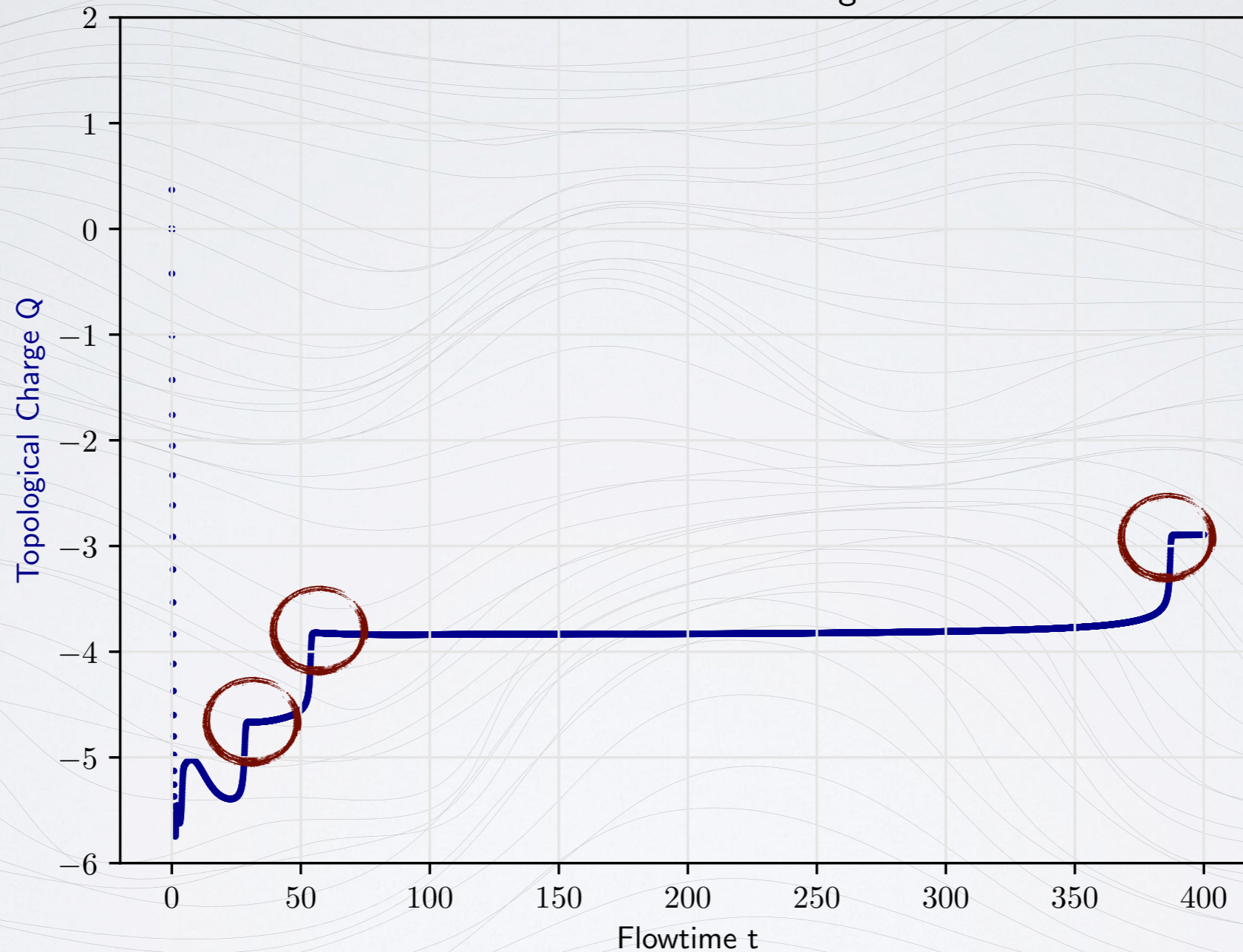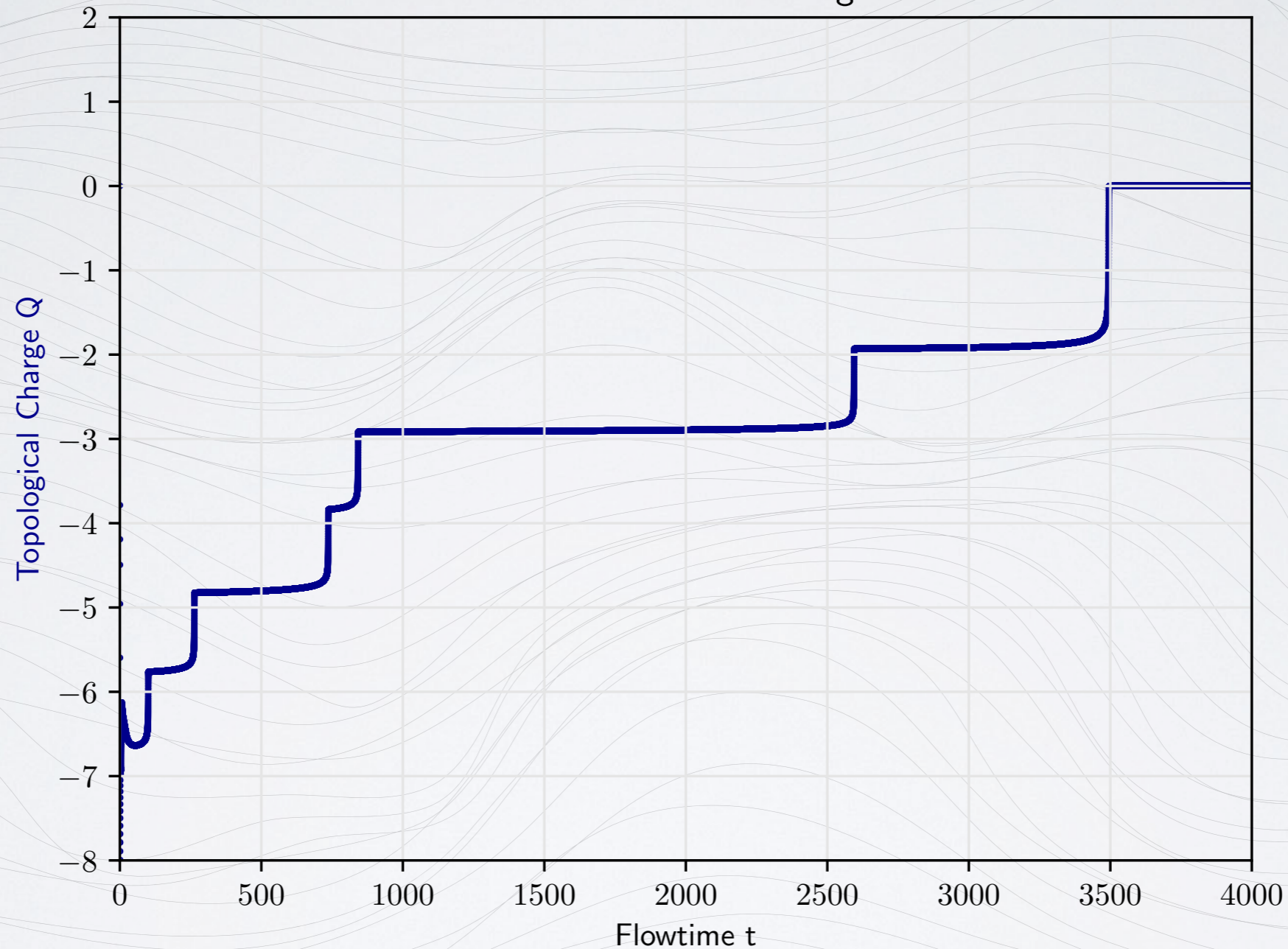
Wilson flow

$$N_C = 4$$

N4L12k15770b71 - Config 244

- Jumps appear even at very large flow times ($> 400\, t_0/a^2$)
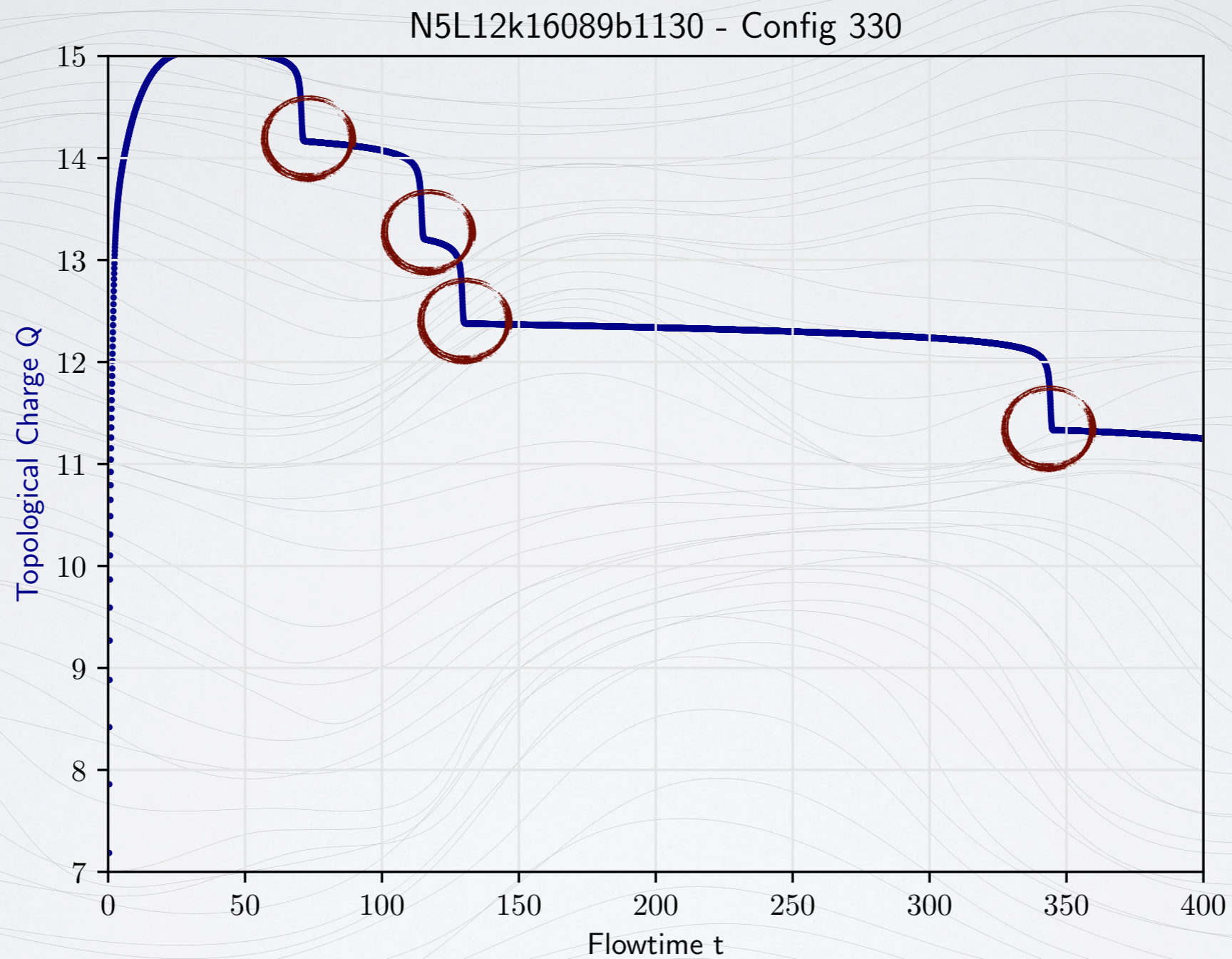
Wilson flow

$$N_C = 4$$

N4L12k15770b71 - Config 244

- As expected the Wilson flow smoothes the links to unity

Wilson flow

$N_C = 5$

N5L12k16089b1130 - Config 330

- Jumps appear even at very large flow times ($> 400\, t_0/a^2$)

Smoothness

- **Smoothness**

$$h = \max\{\mathrm{Re}\,\mathrm{Tr}\,(\mathbf{1} - P_{\mu\nu})\}$$

Lüscher, hep-lat 1006.4518

- Empirical threshold of $h < 0.067$ for $\mathbf{SU}(3)$
- After threshold topological charge is not supposed to change

- Aim: Find similar threshold for $\mathbf{SU}(N_C)$
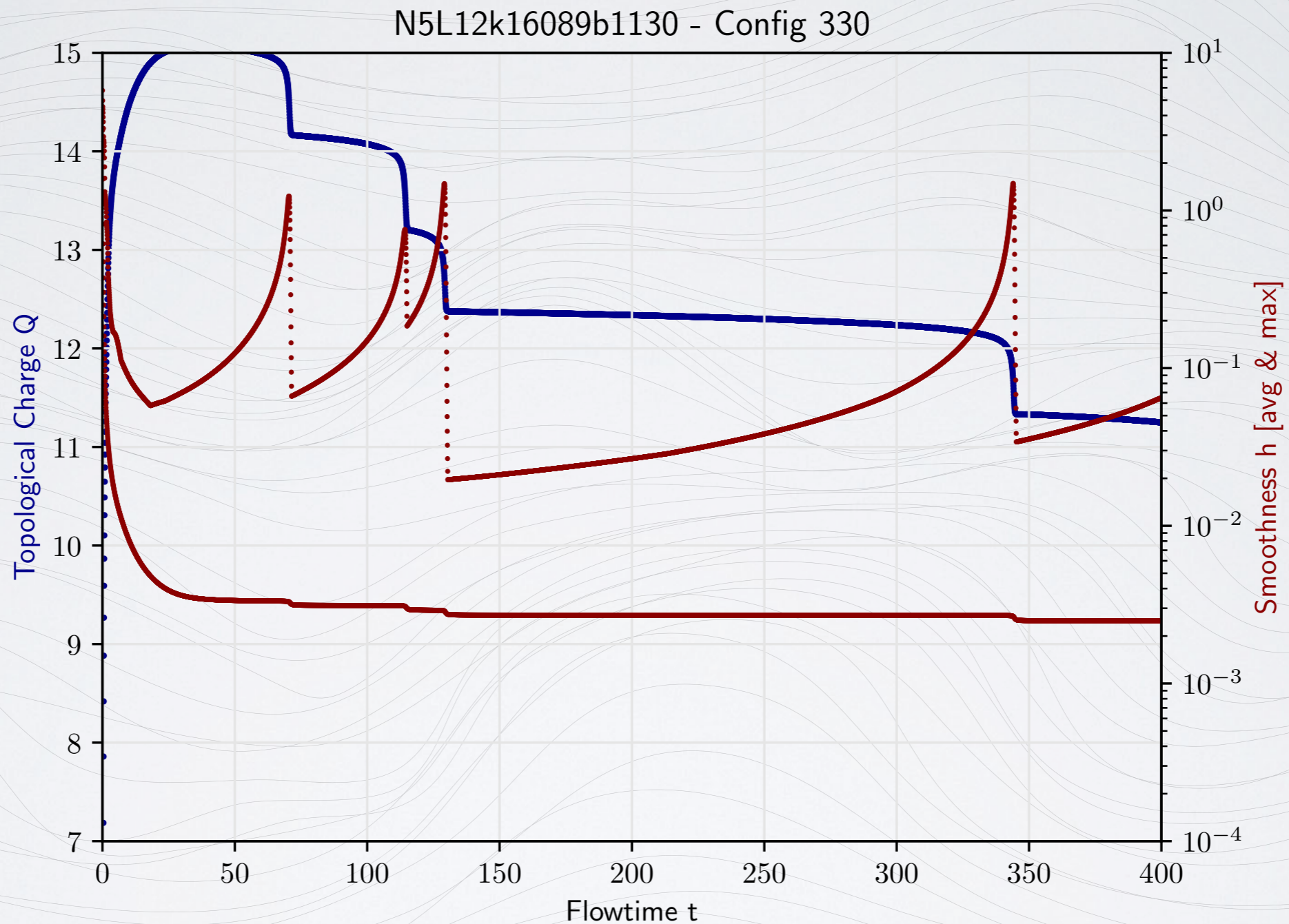
- **Average** of h is related to Energy density

Wilson flow

$N_C = 4$
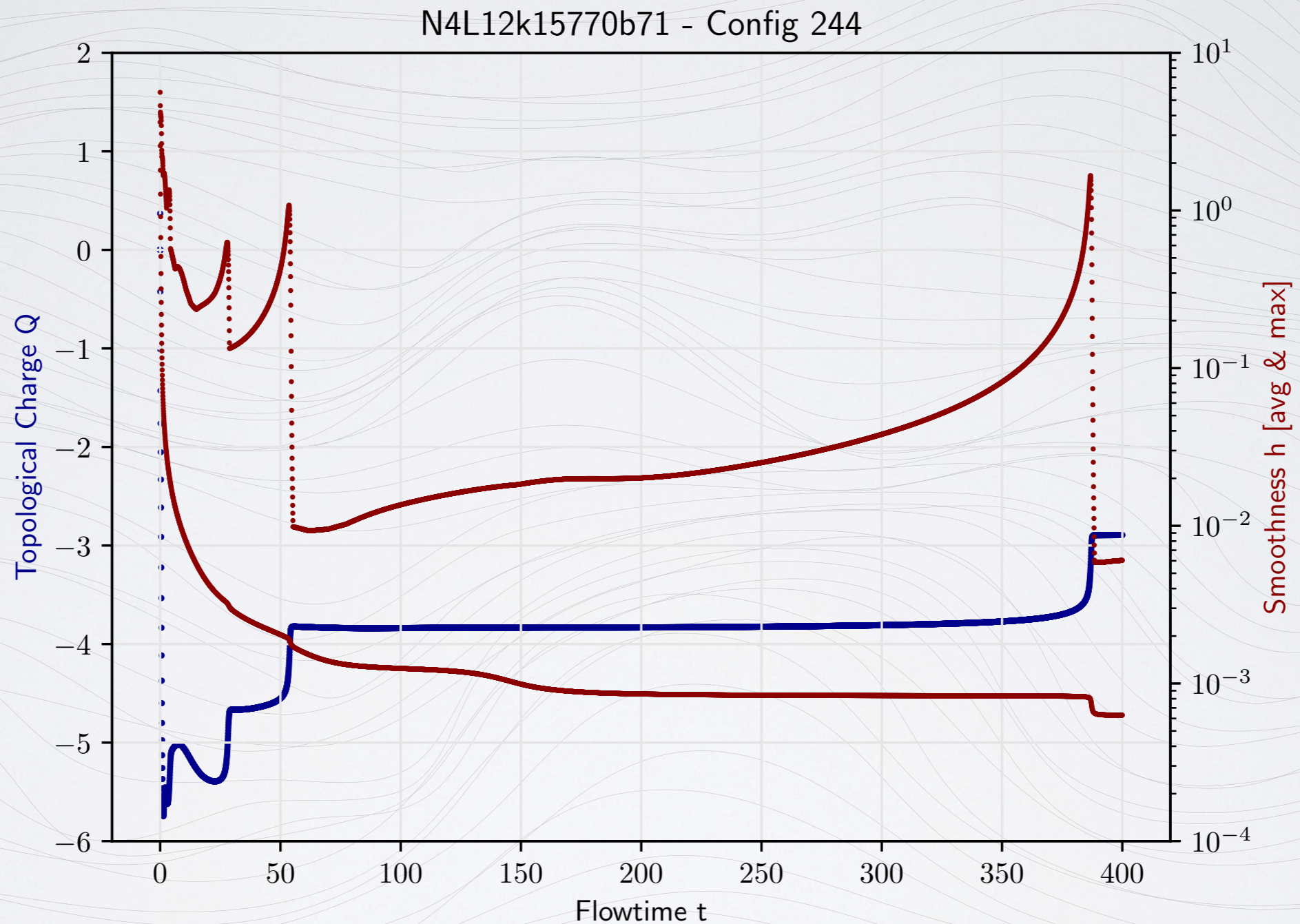
N4L12k15770b71 - Config 244

- Jumps of the smoothness coincide with topo. charge changes
- When to measure the topological charge?

Wilson flow
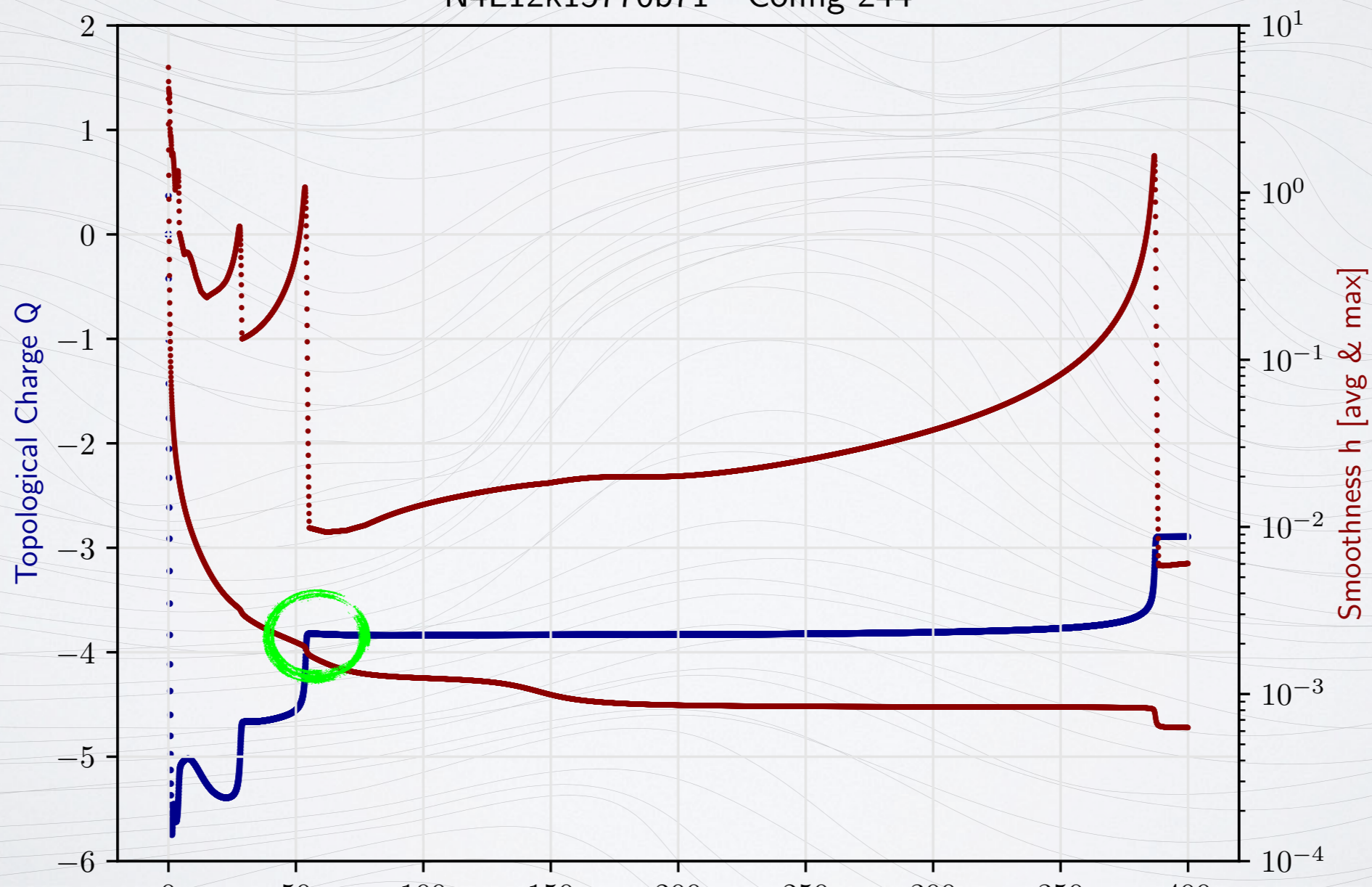
$N_C = 5$

N5L12k16089b1130 - Config 330

- Jumps of the smoothness coincide with topo. charge changes
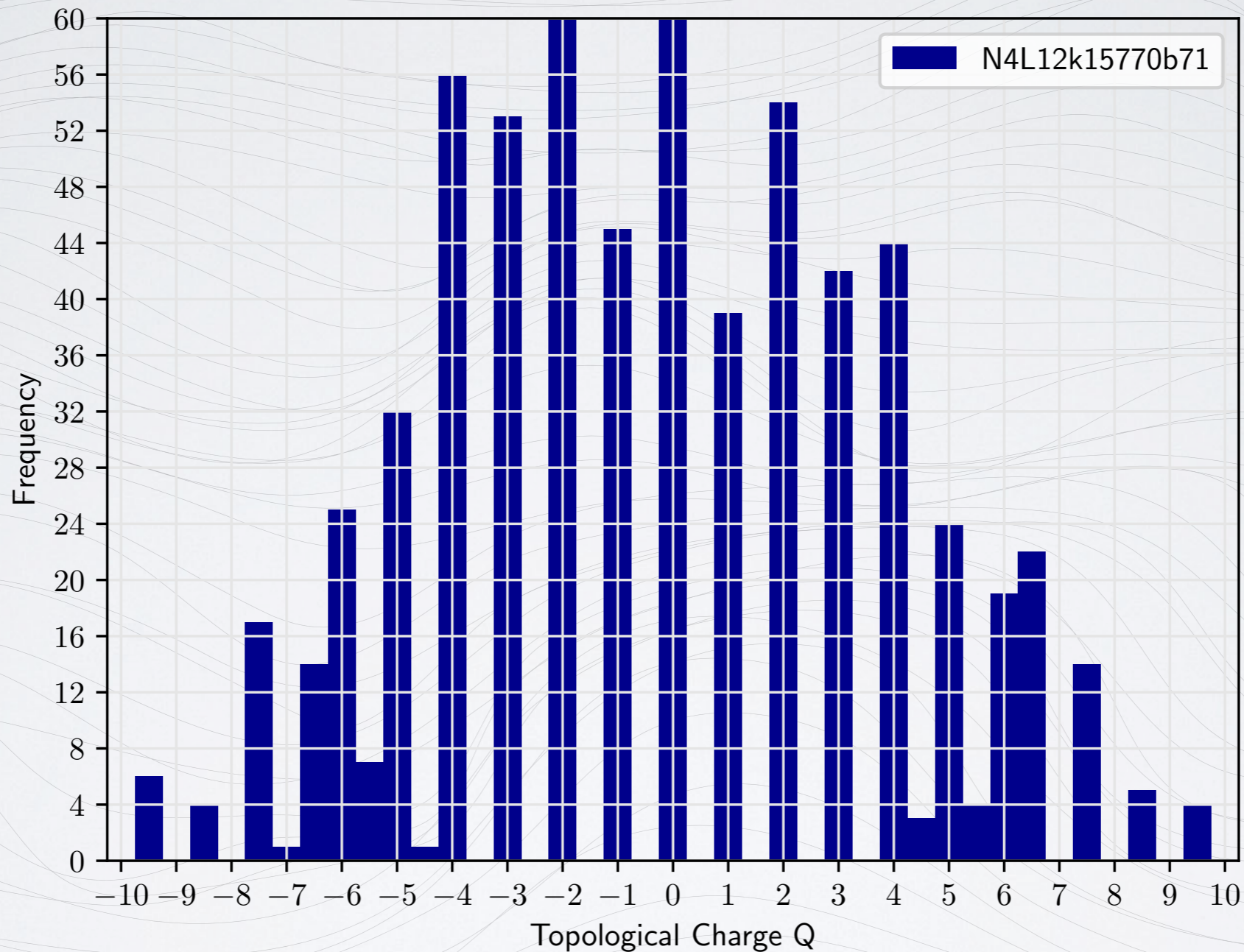- When to measure the topological charge?

Wilson flow

$$N_C = 4$$

- **Strategy (Still under development!)**

  - Measure topological charge when h is minimal
  - Ensure that flow time is large enough, but not too large
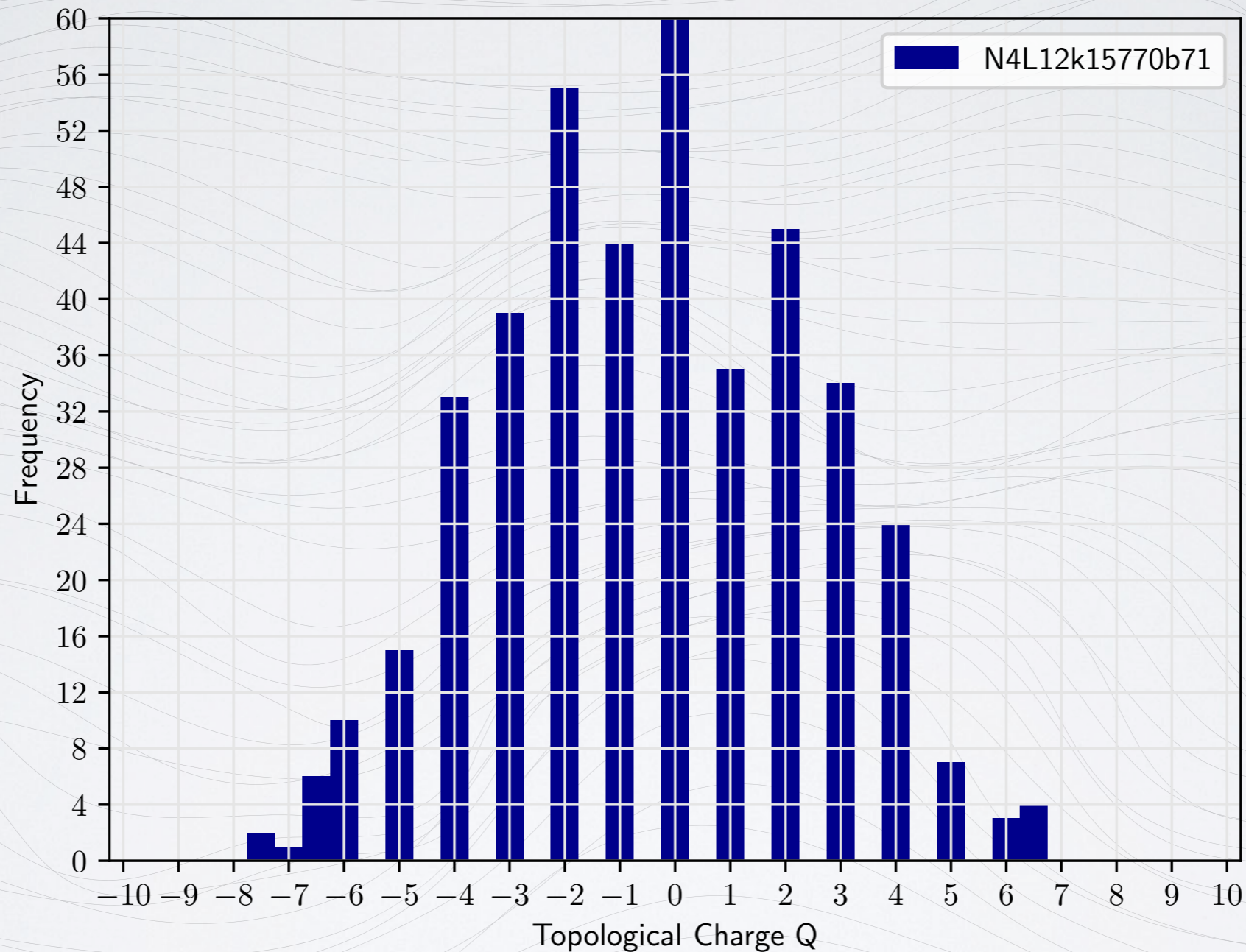
N4L12k15770b71 - Config 244

Histograms

- Coarsest setup
- Fractional charges visible for large $|Q|$

Histograms

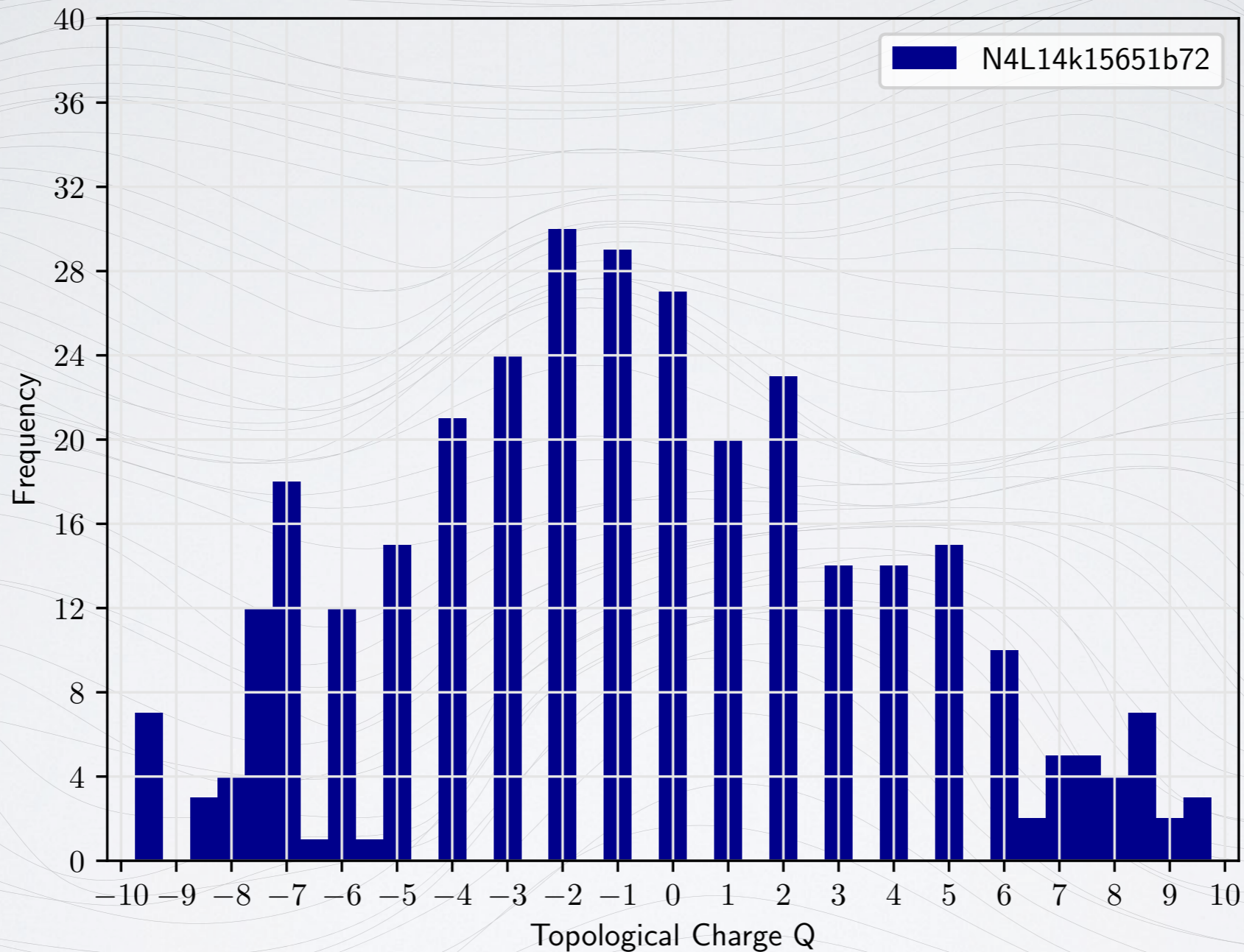- Excluding all configs with $h > 0.01$
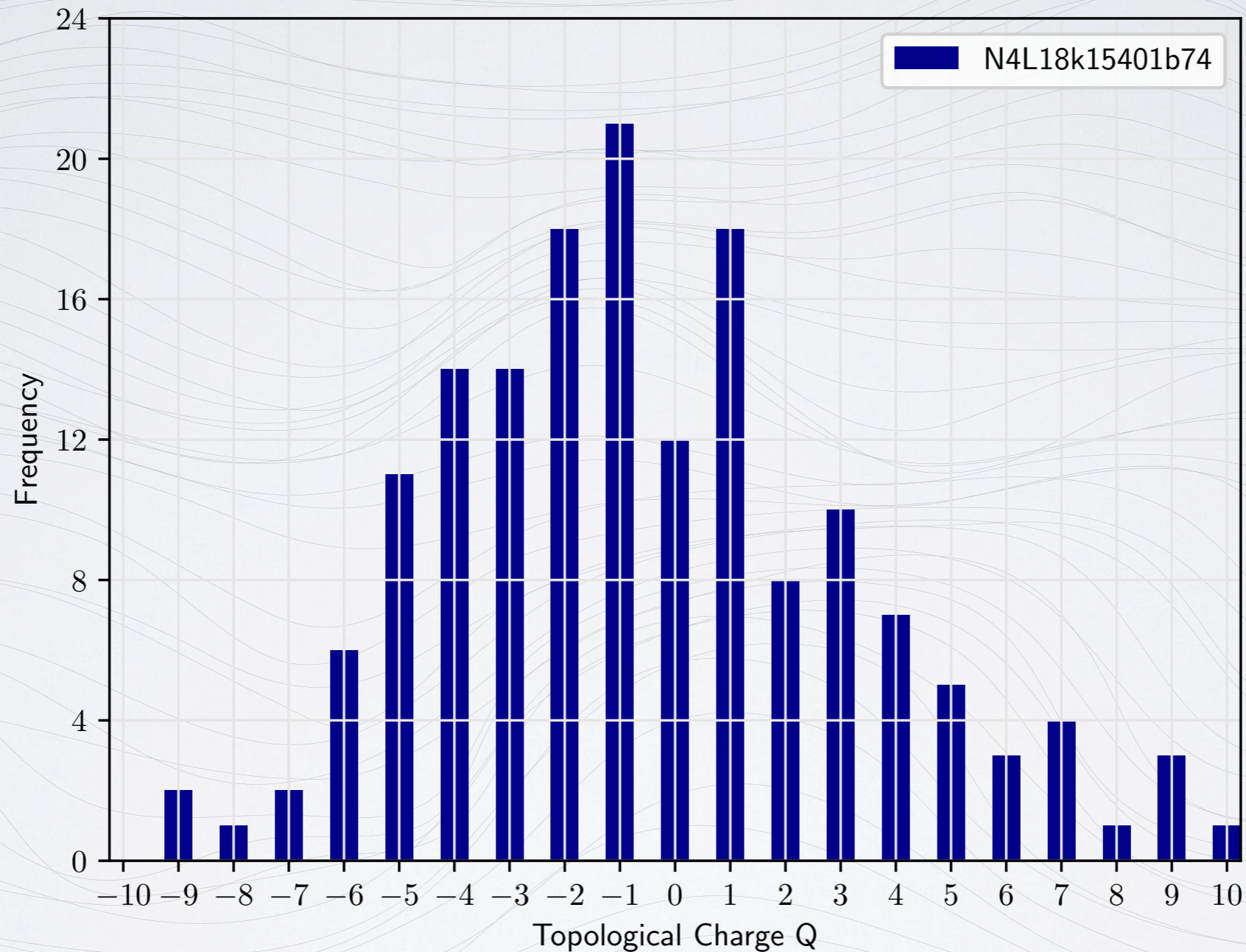- Very few fractional charges still visible for large $|Q|$

Histograms

- Finer setup
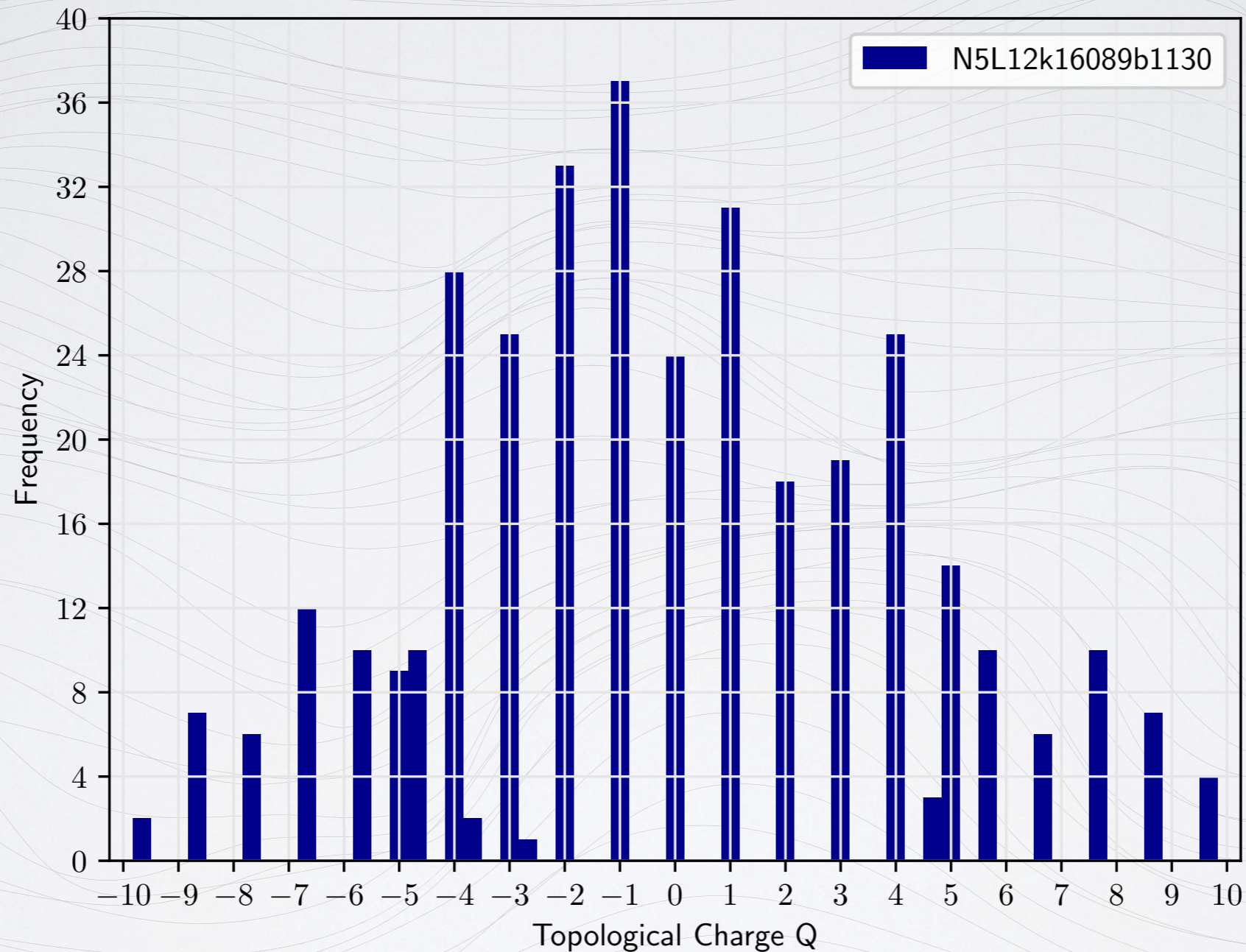- Fractional charges visible for large $|Q|$

Histograms

- Even finer setup
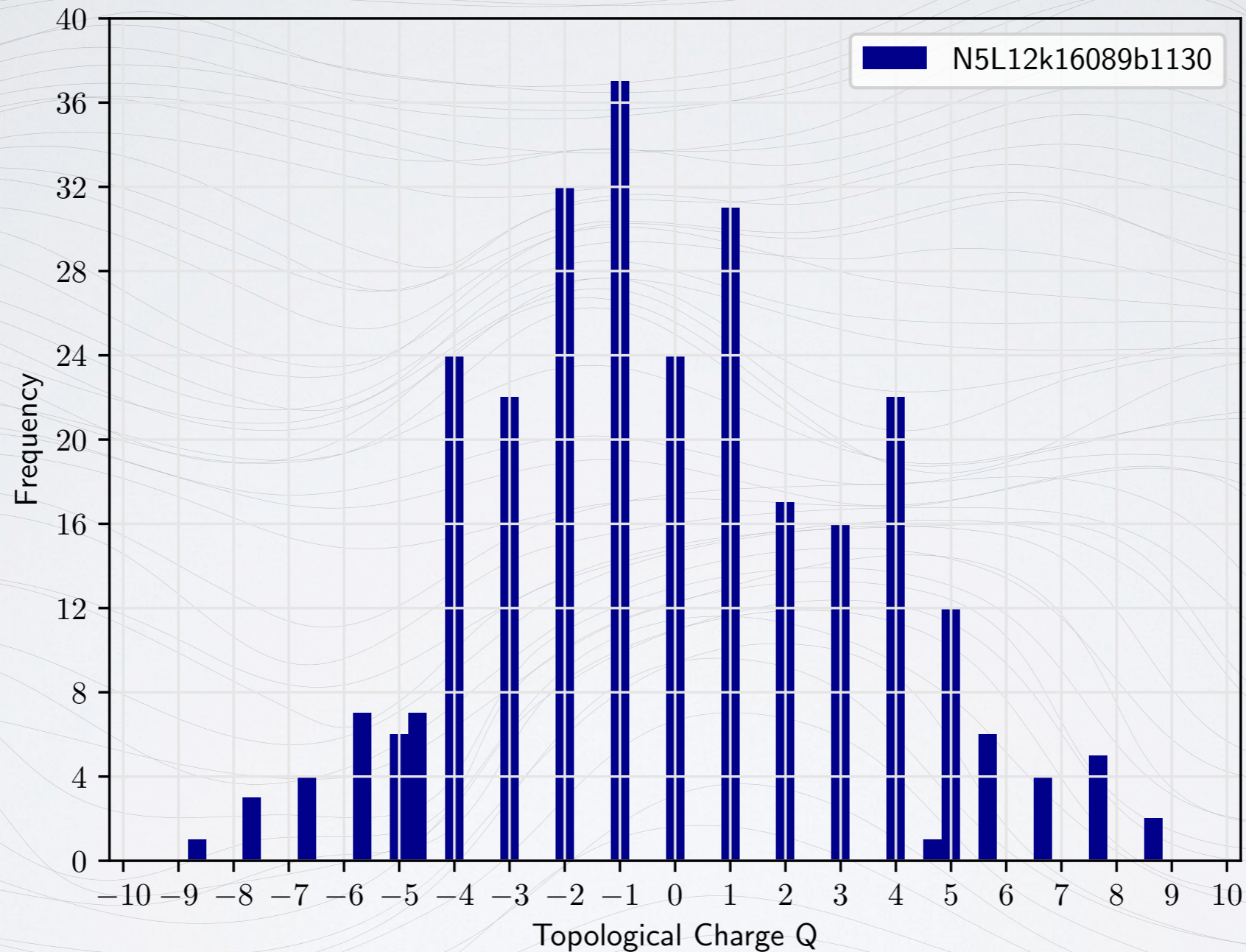- **No** fractional charges visible for large $|Q|$

Histograms

- For $N_C = 5$ fractional charges could be multiples of $1/3$
- Fractional charges visible for large $|Q|$

Histograms
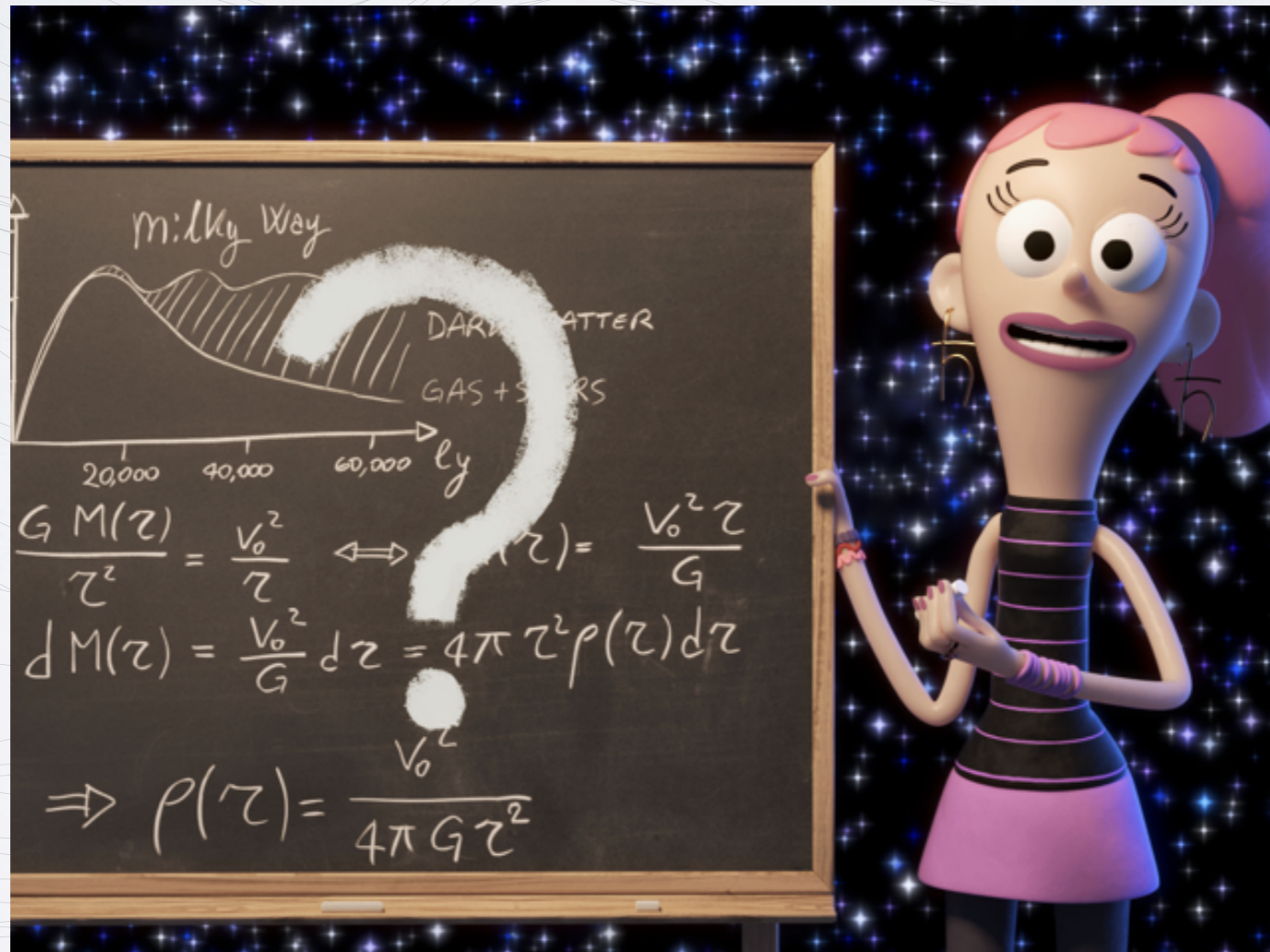
- Excluding all configs with $h > 0.01$
- Fractional charges visible for large $|Q|$

Questions?

Thank you for your attention!

Quantum Kate (orig. Kvante Karina): CP3 Outreach http://www.kvantebanditter.dk/en