SKYRMION NNBAR SUPRESSION

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ArXiv [1110.2188]
with Adam Martin

PROTON DECAY

Local baryon number violating operator

$$\mathcal{L}_{BV} \ni \Lambda \epsilon_{abc} q_a q_b q_c l = \Lambda O_{BV}$$

Fermi's golden rule

$$\Gamma = |\Lambda|^2 |\langle \pi^0, e^+ | O | p \rangle|^2 \rho$$

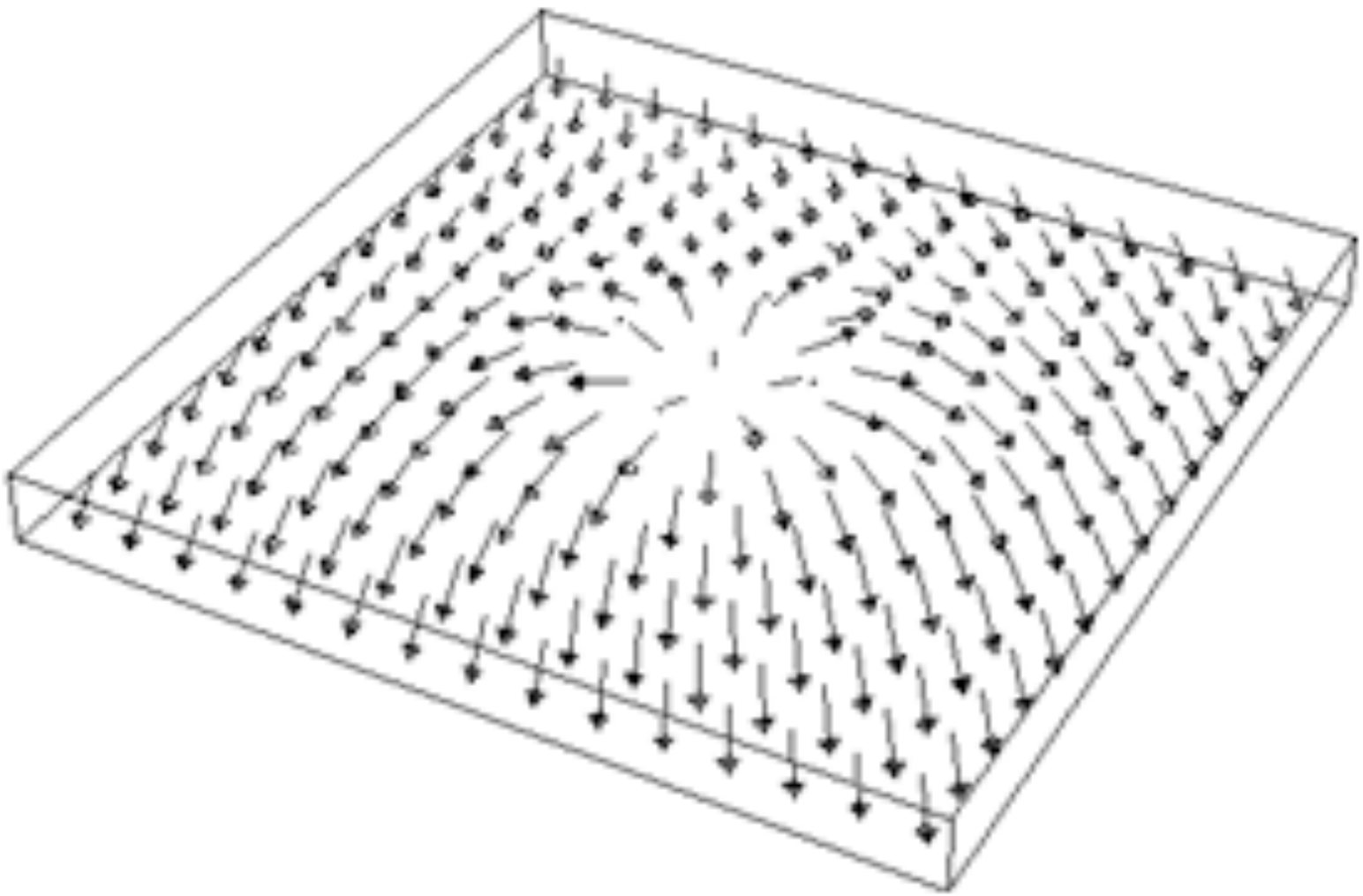
Simple dimensional estimate

$$\Gamma = \frac{m_p^5}{M_{GUT}^4}$$

PROTON DECAY

- Proton is a topological non-trivial configuration of the pion field (Skyrmion)
- Decay of the proton is protected by topology
- Hybrid Skyrmion/bag model decay possible but exponentially suppressed due to tunneling (instanton)

SKYRMION



SKYRMION AS BARYON

Skyrme current

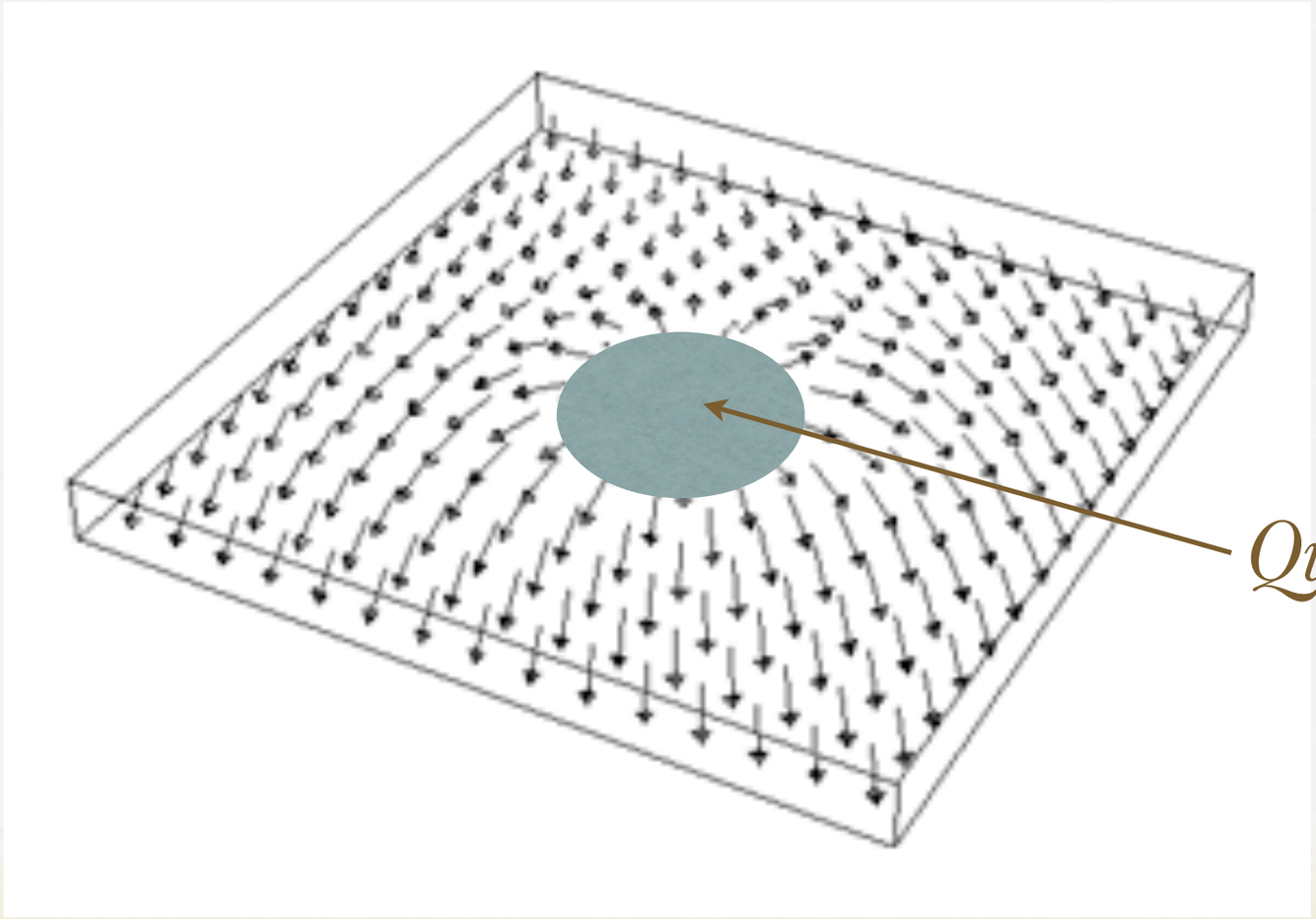
$$B^\mu = \frac{\epsilon^{\mu\nu\alpha\beta}}{24\pi^2}\mathrm{tr}X_\nu X_\alpha X_\beta$$

$B=\int B^0$=winding number=baryon number

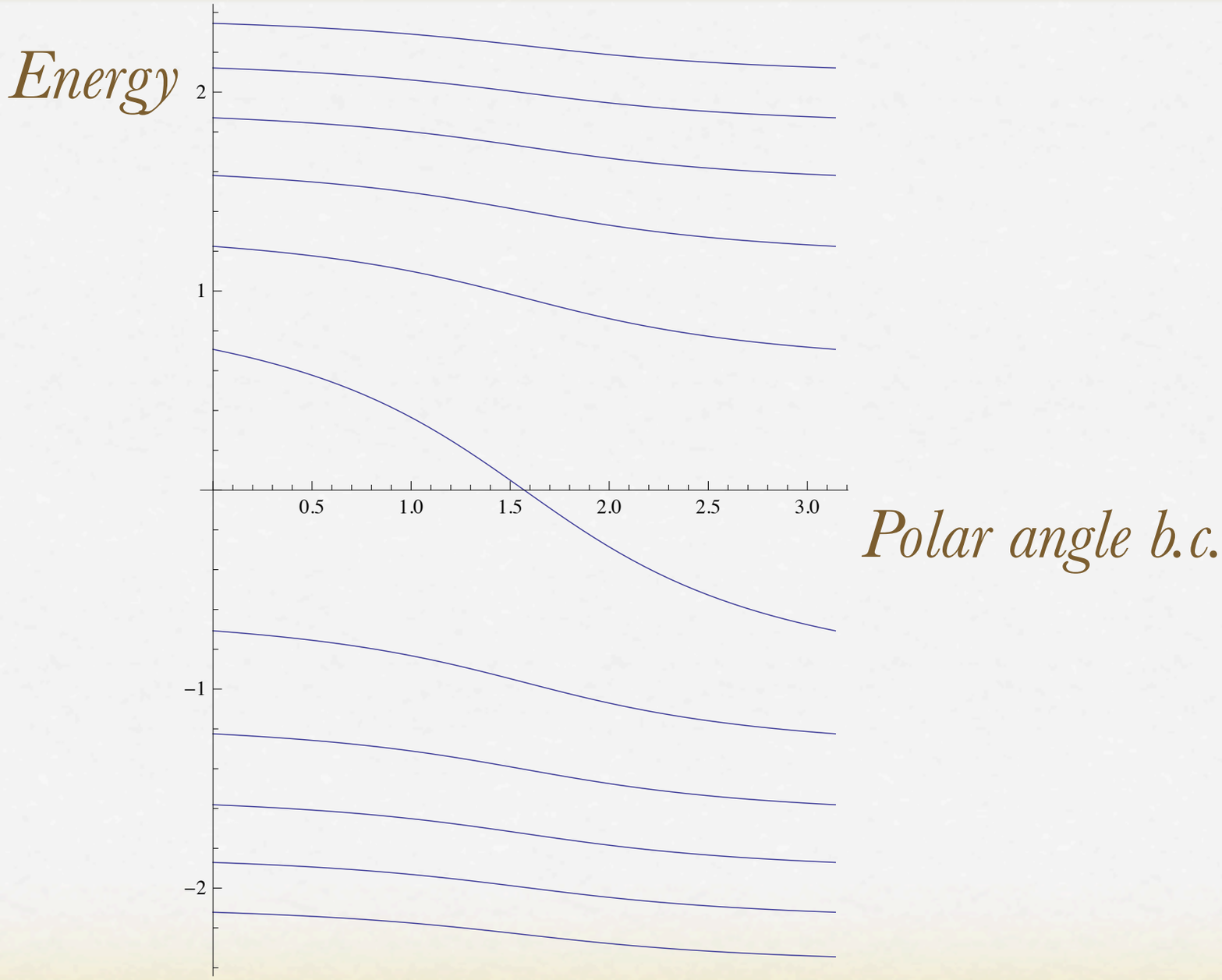
Skyrmion is solitonic description of protons/neutrons
Skyrmions are stable due to topology

CHIRAL BAG

Supplement the Skyrmion with a nucleus (bag) of quarks



QUARK SPECTRUM



BARYON NUMBER

Skyrmion baryon number

$$B_{sk} = [F(r)-\sin(2F(r))/2]/\pi$$

Baryon number of the bag needs appropriate definition

$$B_{bag} = -1/2\sum \mathrm{sgn}(E)=1-[F(r)-\sin(2F(r))/2]/\pi$$

Jaffe-Goldstone [PRL V51, N17, P1518]

Bag baryon current B^{μ} matches Skyrme top. current B^{μ}

PROTON DECAY

- Due to the bag, baryon number is not a topological conserved quantity!
- Mass of the proton has a big component from the twisting of pion field. Not necessarily from the valence quarks.
- If the Skyrmion is twisted enough there are no valence quarks! The quarks dived in the vacuum.
- Proton decay kinematically forbidden!

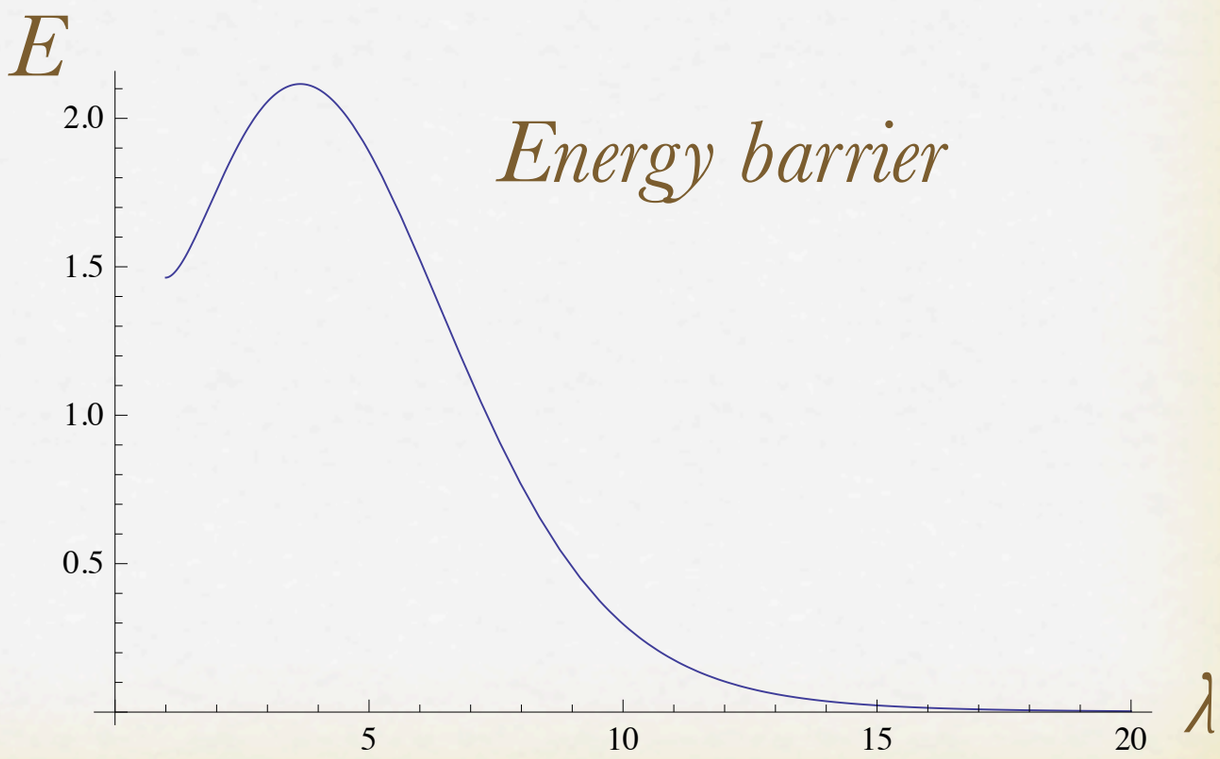
NAIVE DECAY

Forget about the bag interior. Just the decay of the Skyrmion.

Shrink the Skyrmion inside the bag to decay it!

Effective Lagrangian for the scale factor λ

$$\mathcal{L} = (A/\lambda + B/\lambda^3)\dot{\lambda}^2 + V(\lambda)$$

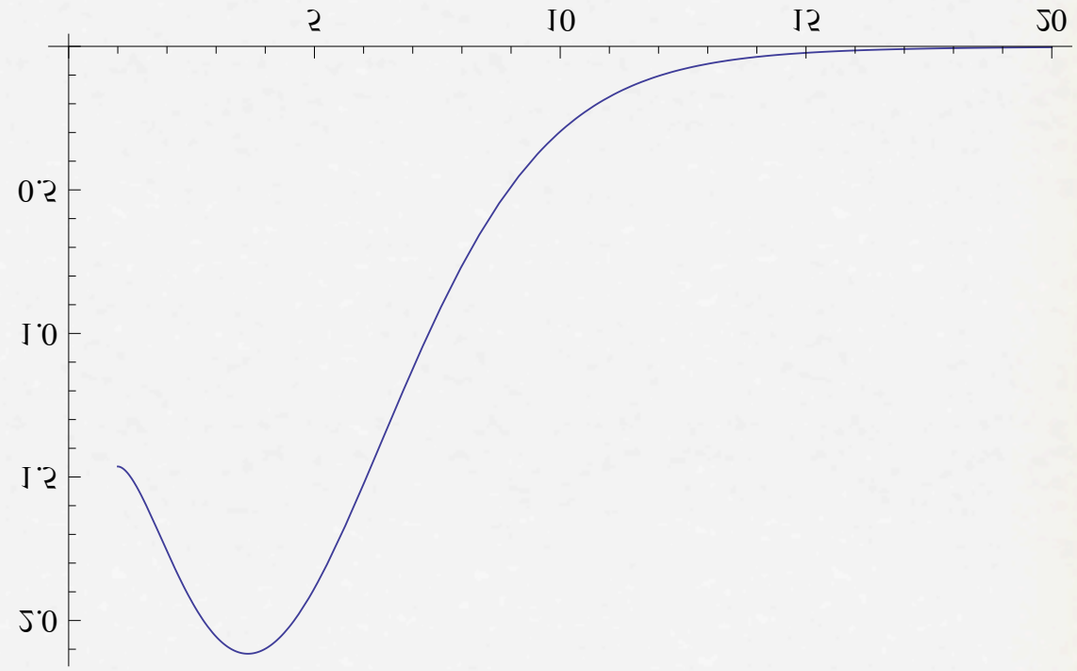


Energy barrier

INSTANTON

Skyrmion meta-stable state

find classical "bounce" solution



Path-integral gives $\frac{1}{\sqrt{\det}} e^{-S}$

Following Coleman: Instanton gas approx. $E \to E + i(\det')^{-\frac{1}{2}} e^{-S}$

Decay rate is the width, therefor $\Gamma = (\det')^{-\frac{1}{2}} e^{-S}$

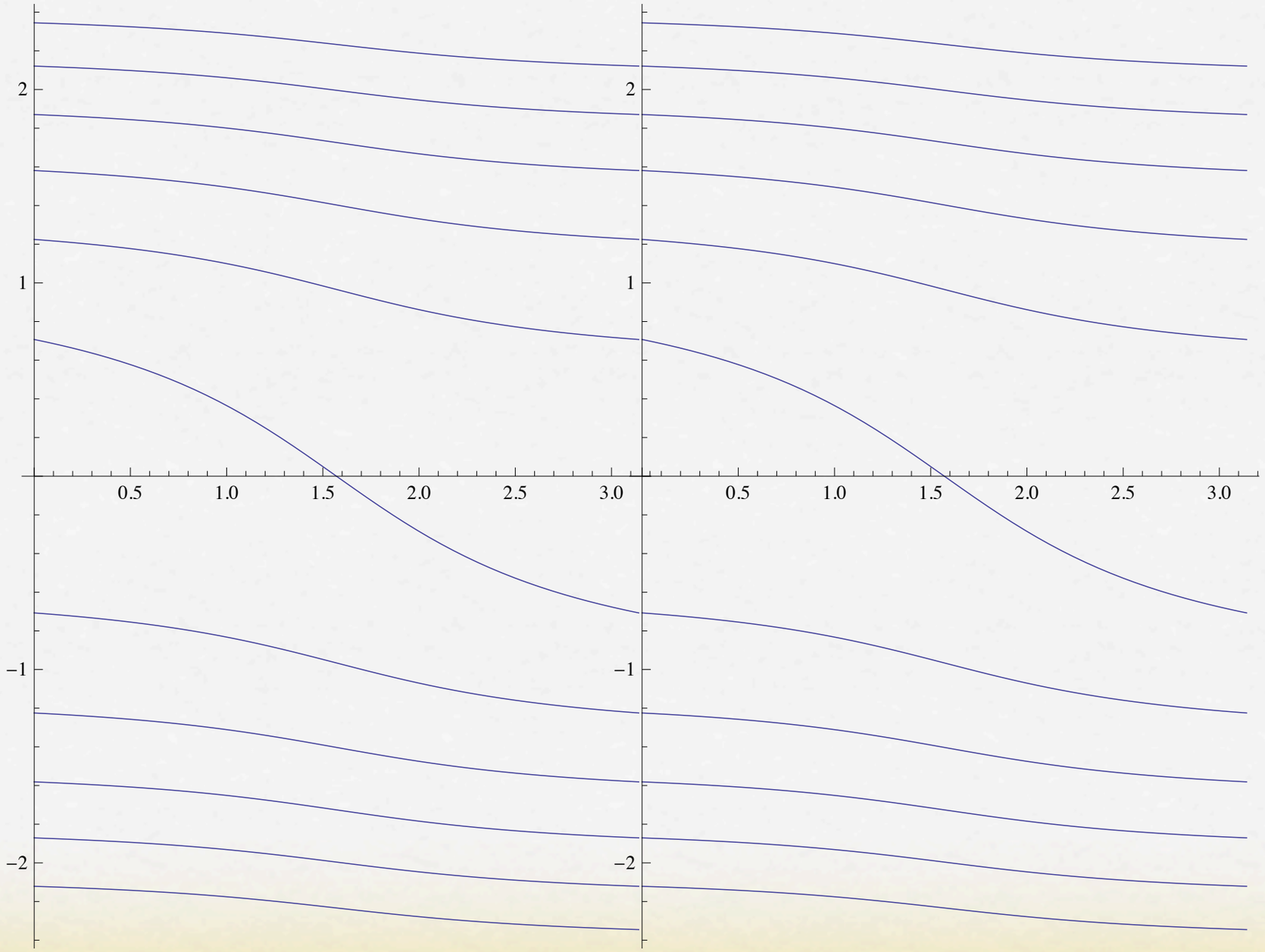
ADD THE QUARKS

- Adding quarks stabilizes the proton. In the presence of the bounce instanton the fermionic quarks are severely suppressed due to “almost zero-modes”
- In the presence of BNV operator these zero-modes are cancelled and we get proton decay but suppressed by the instanton

NNBAR ME

- Interested in <nbar|udd udd|n>
- Baryon violating operator is $\Delta B=2$
- both n and nbar are degenerate groundstates
- Instanton between Skyrmion wrapped one way and the opposite way

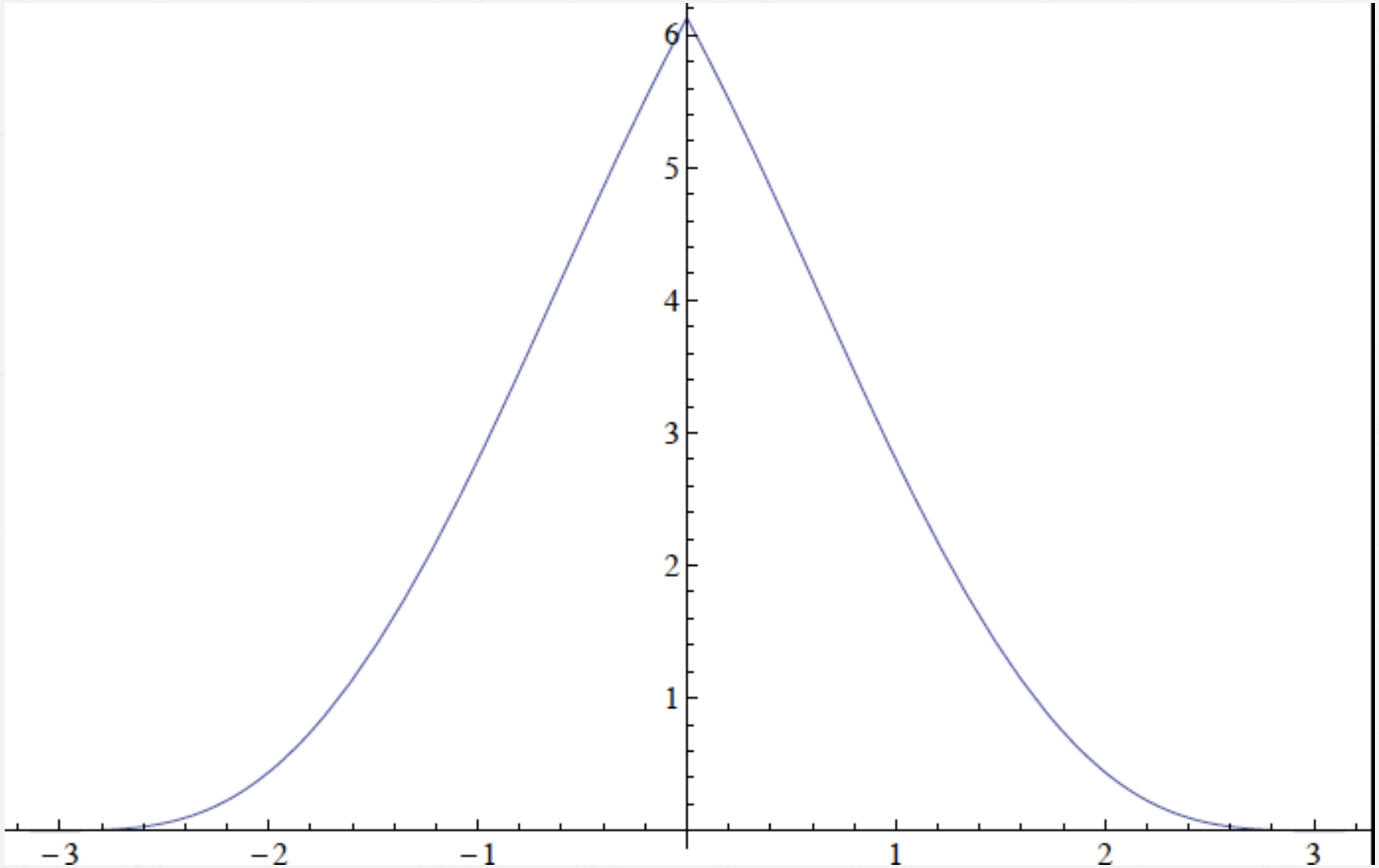
INSTANTON



ZERO MODES

- There are two energy levels crossing zero, so the determinant has two zero modes.
- Therefore nnbar oscillations are forbidden in this model. As it should because without BNV operator there should be no oscillations.
- In presence of such an operator the zero modes can be absorbed and the instanton can be proceed.

INSTANTON BARRIER



RESULT

- Result depends sensitive to the bag radius used
- We used r=0.3 (Reasonable number)
- Matrix element is suppressed 10^{-5}
- We get a suppression for the of $\sim 10^{-10}$
- Hadronic matrix element severely suppressing proton decay!

DISCUSSION

- We calculated hadronic matrix elements including non-perturbative QCD effects resulting in suppression.
- This suppression can be sizeable.
- Drawback not a very stable calculation due to bag size.