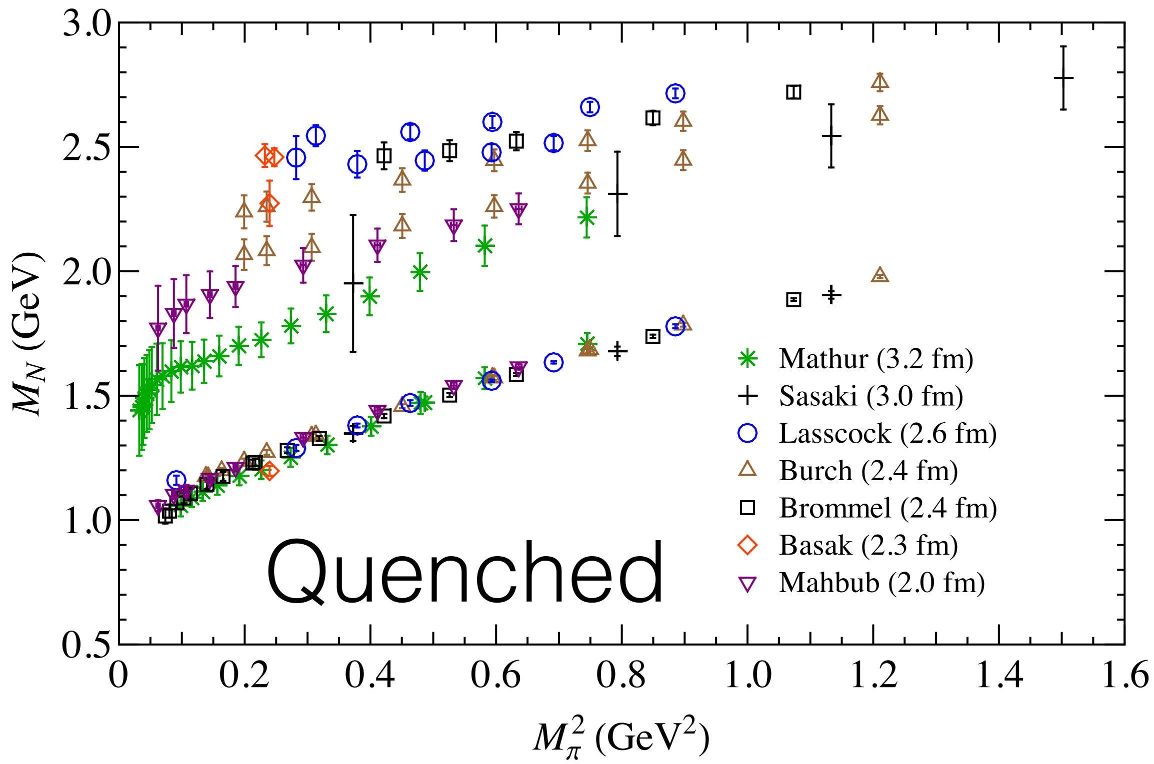
The Roper resonance from spatially large interpolation fields

The χQCD Collaboration:

Mingyang Sun (speaker), Keh-Fei Liu, Yi-Bo Yang, Ying Chen, Ming Gong, Terrence Draper, Raza Sabbir Sufian, Andrei Alexandru

Motivation

- Radial excitation of nucleon
- Roper mass experimental value: 1440 MeV ($\Gamma \approx 300$ MeV)

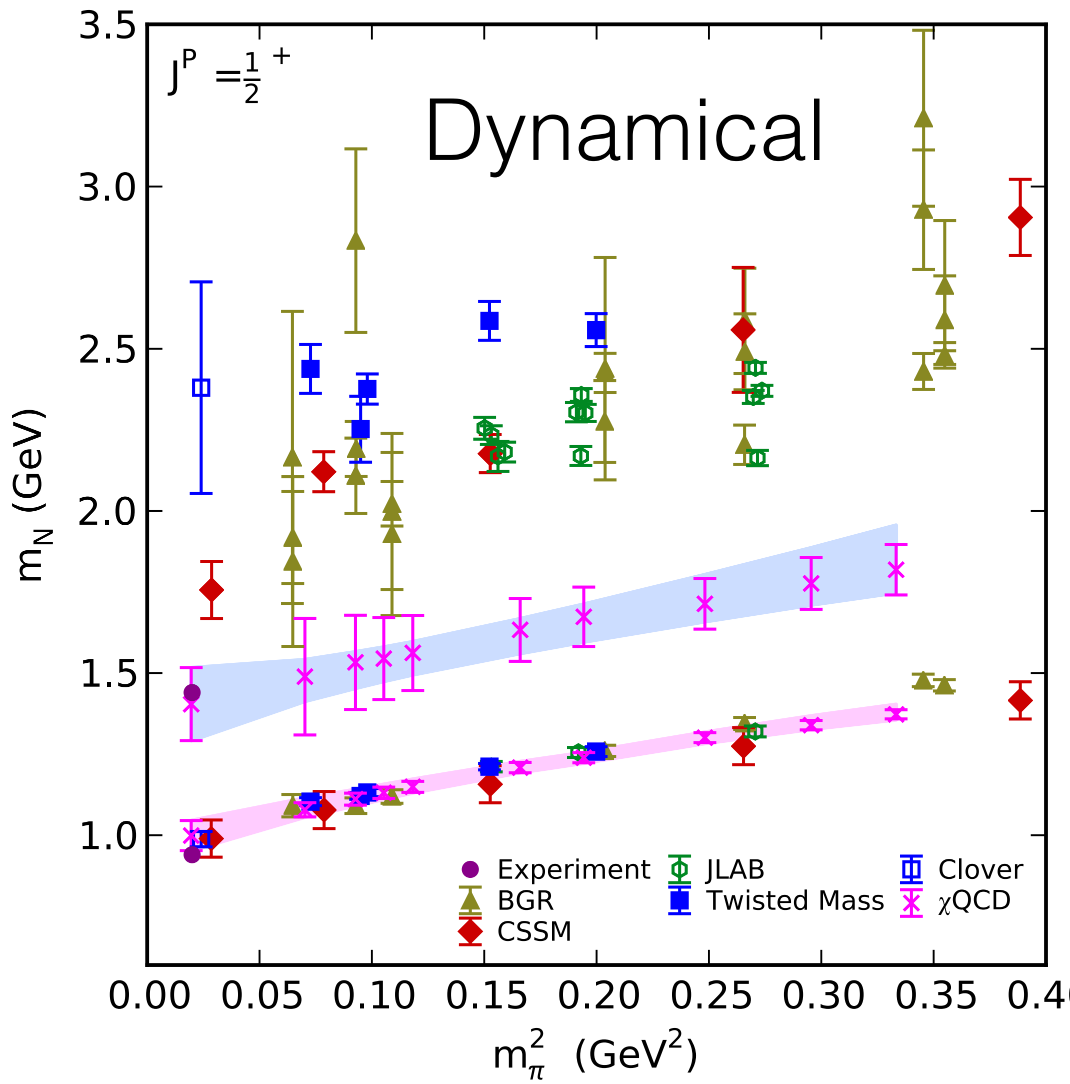


Overlap

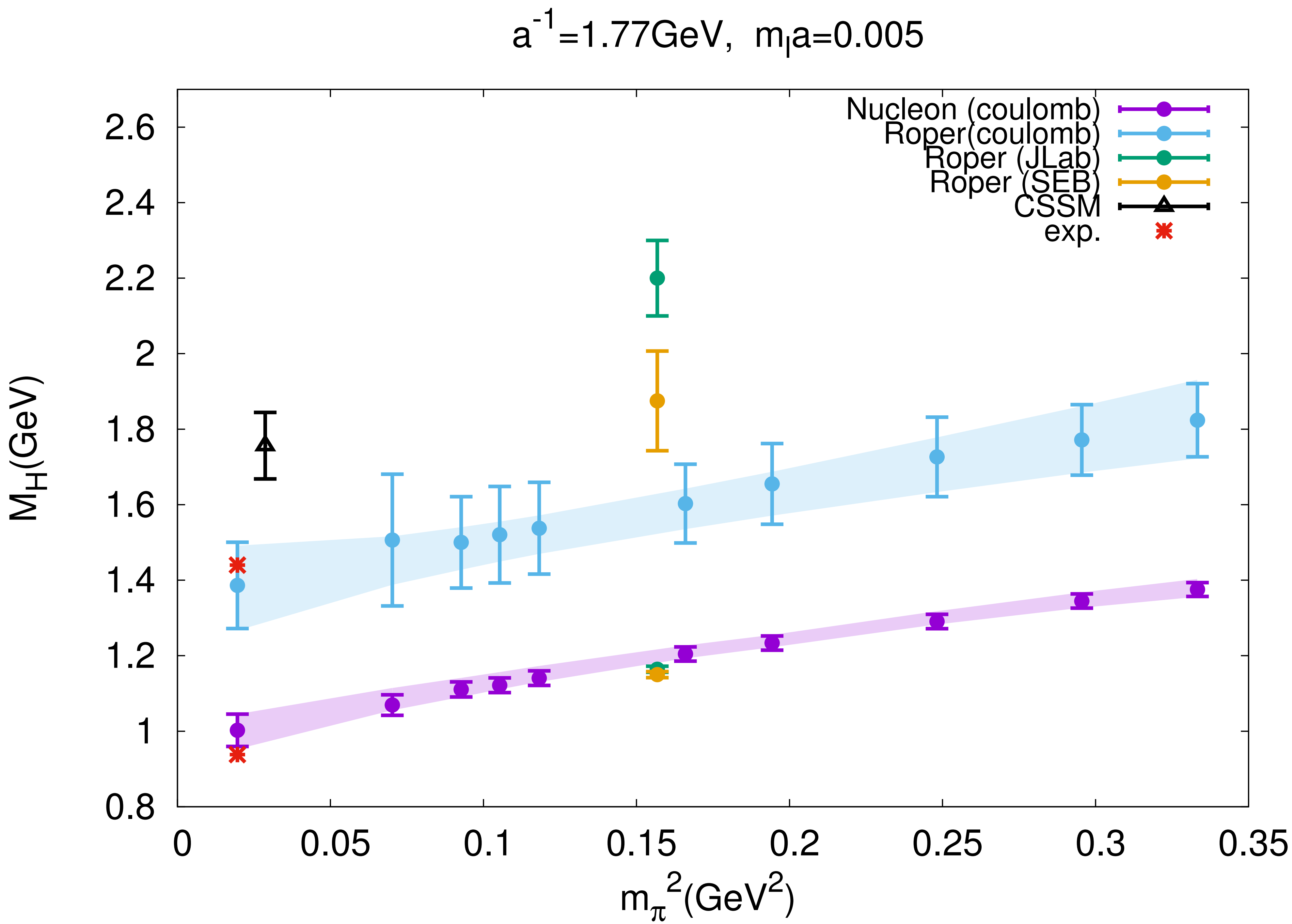
Sequential Empirical Bayesian

Ying Chen et al., arXiv:hep-lat/0405001 (2004)

Huey-Wen Lin, CJP, **49** 827 (2011)



Keh-Fei Liu et al., arXiv:1403.6847 (2014)



Keh-Fei Liu et al., arXiv:1403.6847 (2014)

Ground State Elimination (GSE) method

Consider two correlators

$$C_1 = A_1 e^{-m_0 t} + B_1 e^{-m_1 t} + \cdots$$
$$C_2 = A_2 e^{-m_0 t} + B_2 e^{-m_1 t} + \cdots$$

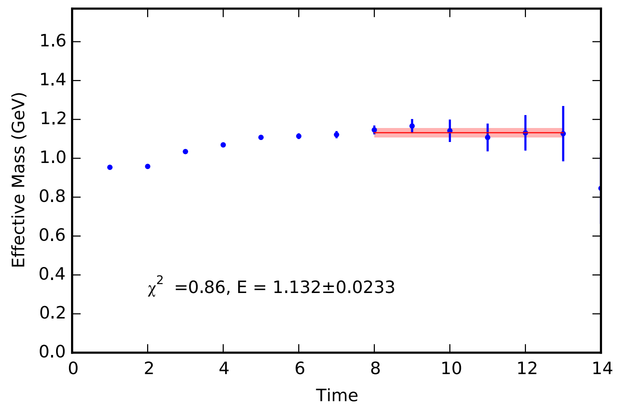
$$\exists\ a, b \ \Rightarrow \ aC_1 + bC_2 \sim e^{-m_1 t} + \cdots$$

Lattices used

- RBC/UKQCD 2+1 flavor domain wall $24^3 \times 64$, $a \approx 0.112$ fm, $m_\pi = 330$ MeV, with overlap fermion on top, 200 configurations
- JLab 2+1 flavor anisotropic clover $24^3 \times 128$, $a \approx 0.123$ fm, $m_\pi = 390$ MeV, 760 configurations

Steps

1. Take two correlators C_1, C_2

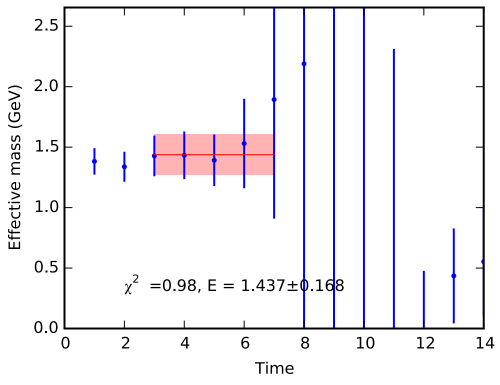


2. Fit for proton, note the fitting window

3. Take linear combination of the two correlators with parameter a: $C = C_1 + aC_2$

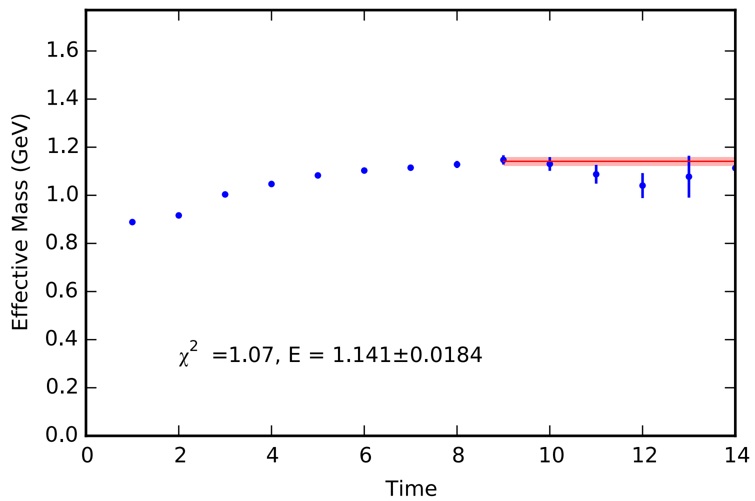
4. For each jackknife sample, fit C to zero in the proton fitting window to fix a

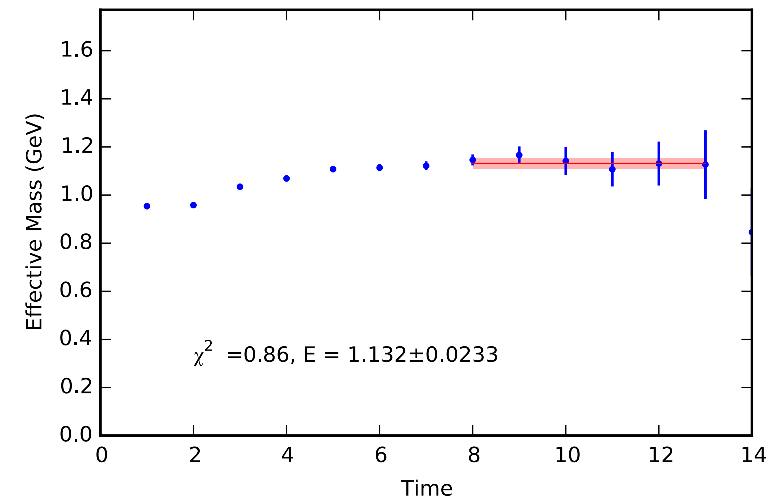
5. For each jackknife sample, fit C for mass of the 1st excited state.



χQCD

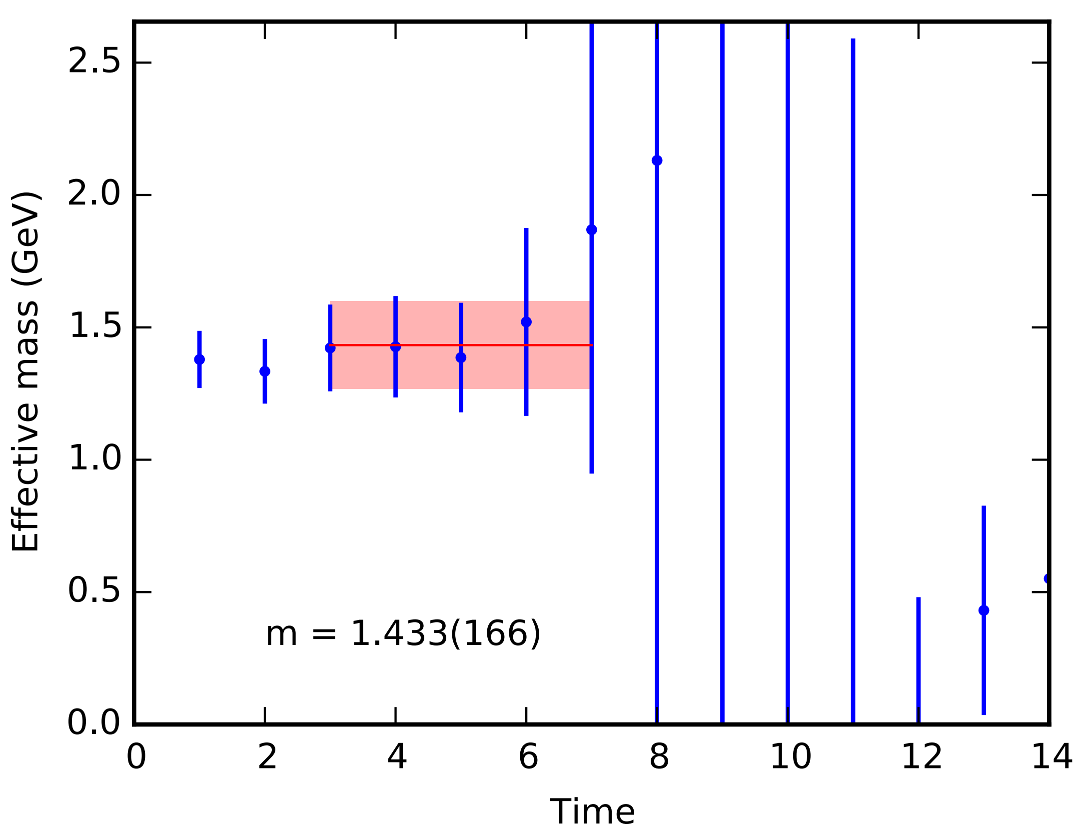
Overlap on domain wall

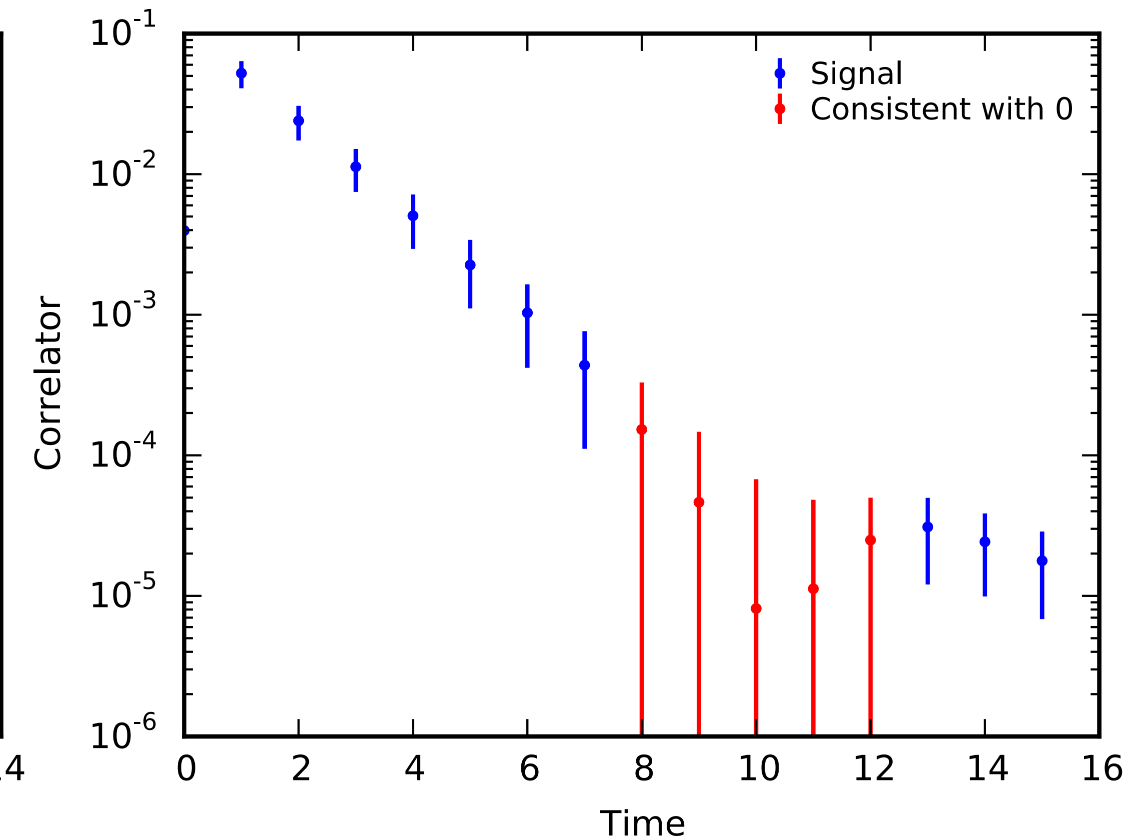


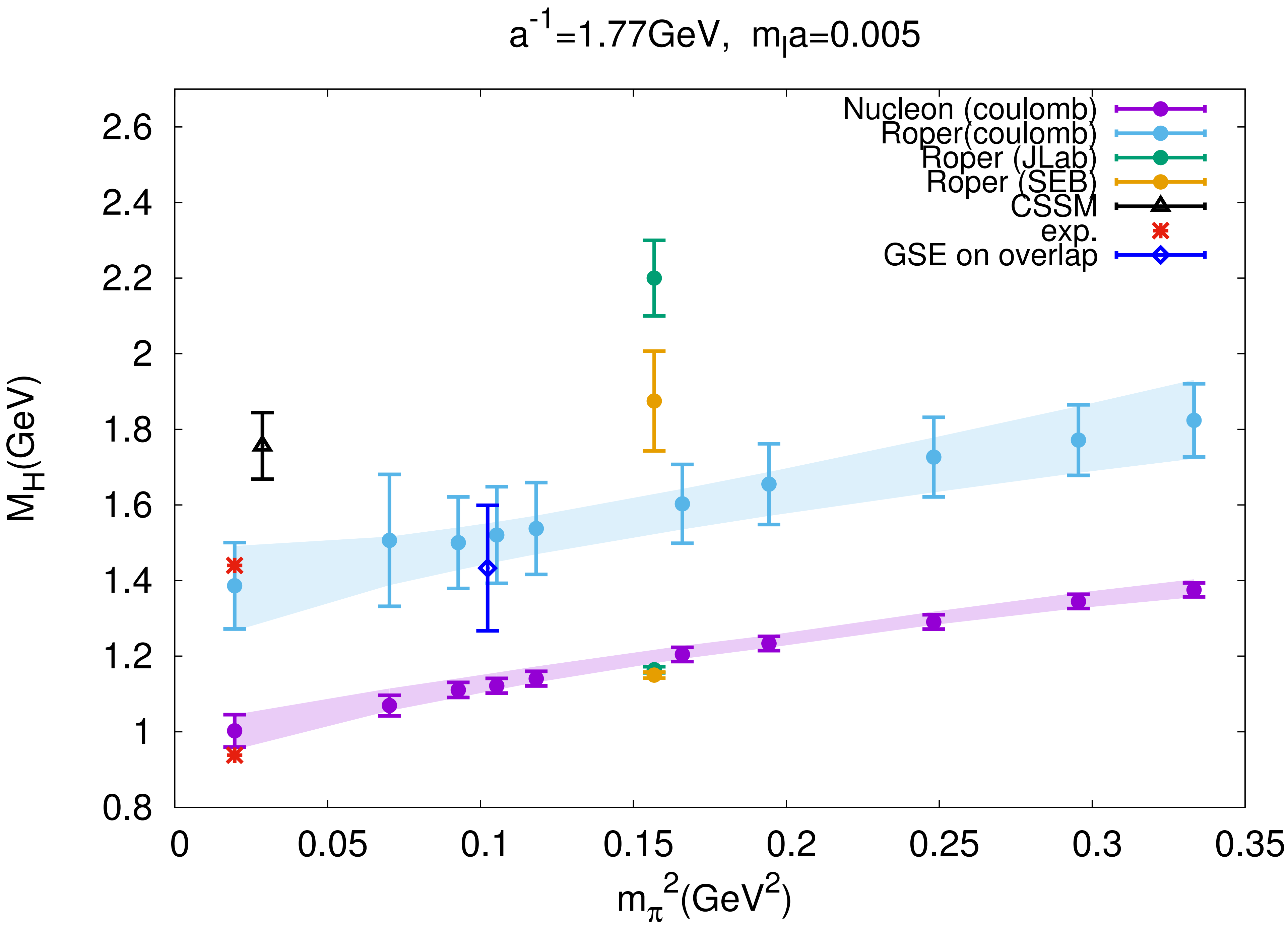


Coulomb wall source, point sink

Smeared source (RMS $r \approx 1$ fm), point sink

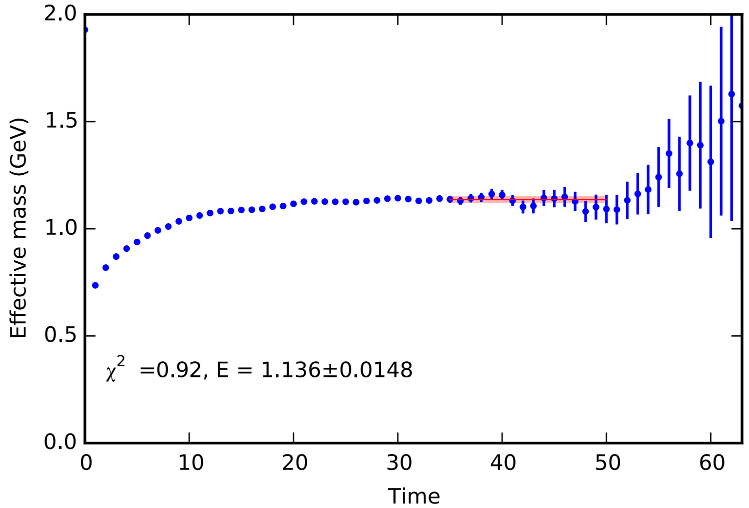




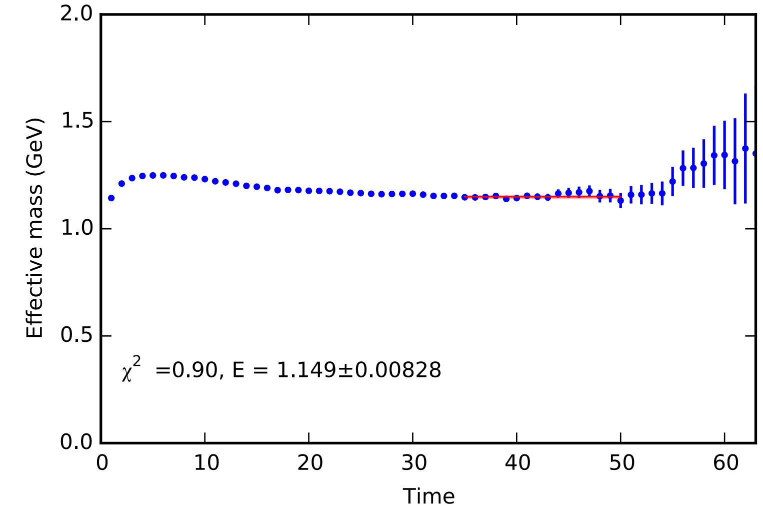


a^-1=1.77GeV, m_l a=0.005
Nucleon (coulomb)
Roper(coulomb)
Roper (JLab)
Roper (SEB)
CSSM
exp.
GSE on overlap
M_H(GeV)
m_π^2(GeV^2)
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35

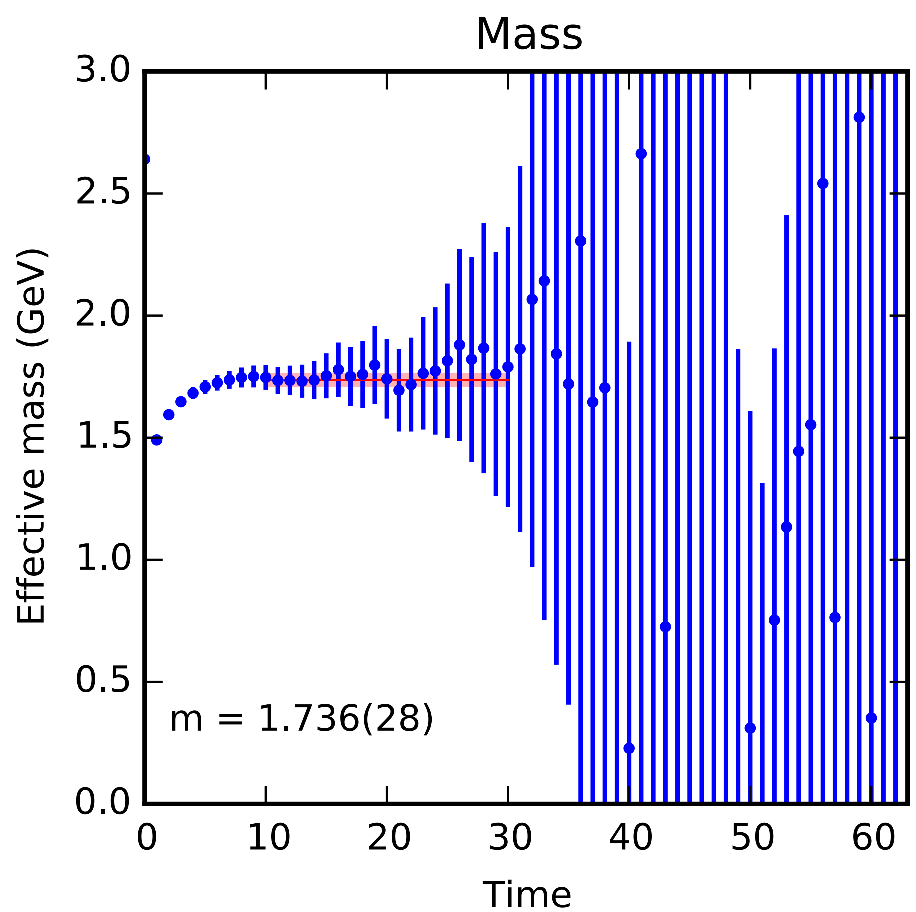
Anisotropic Clover

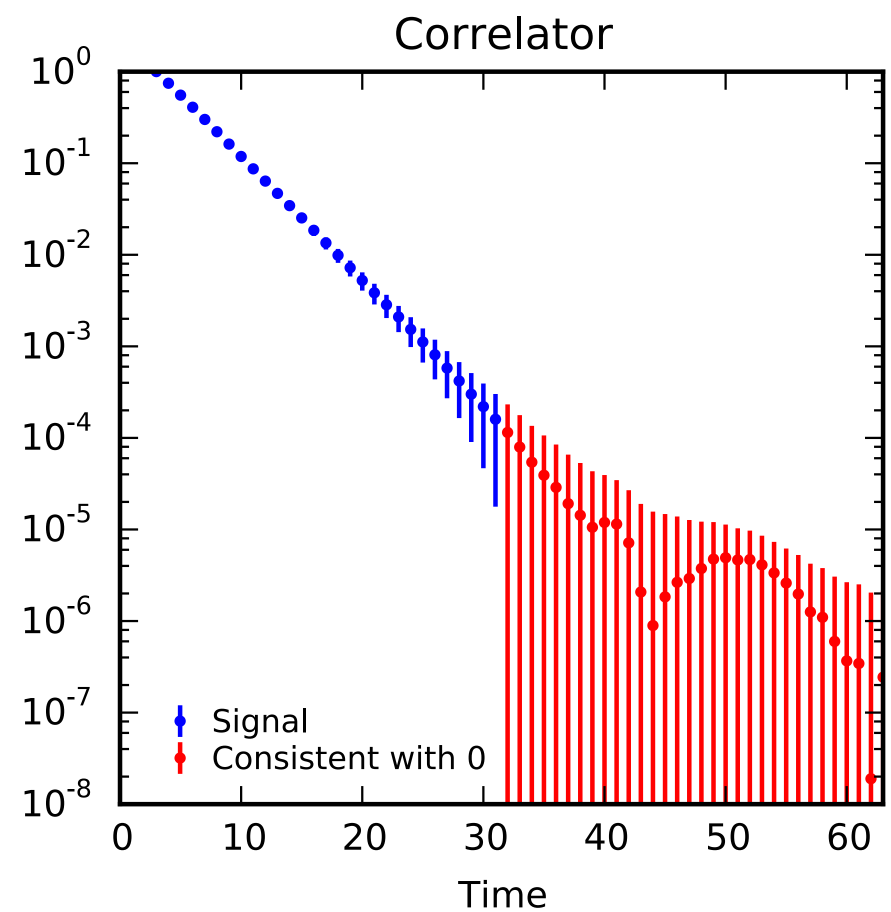


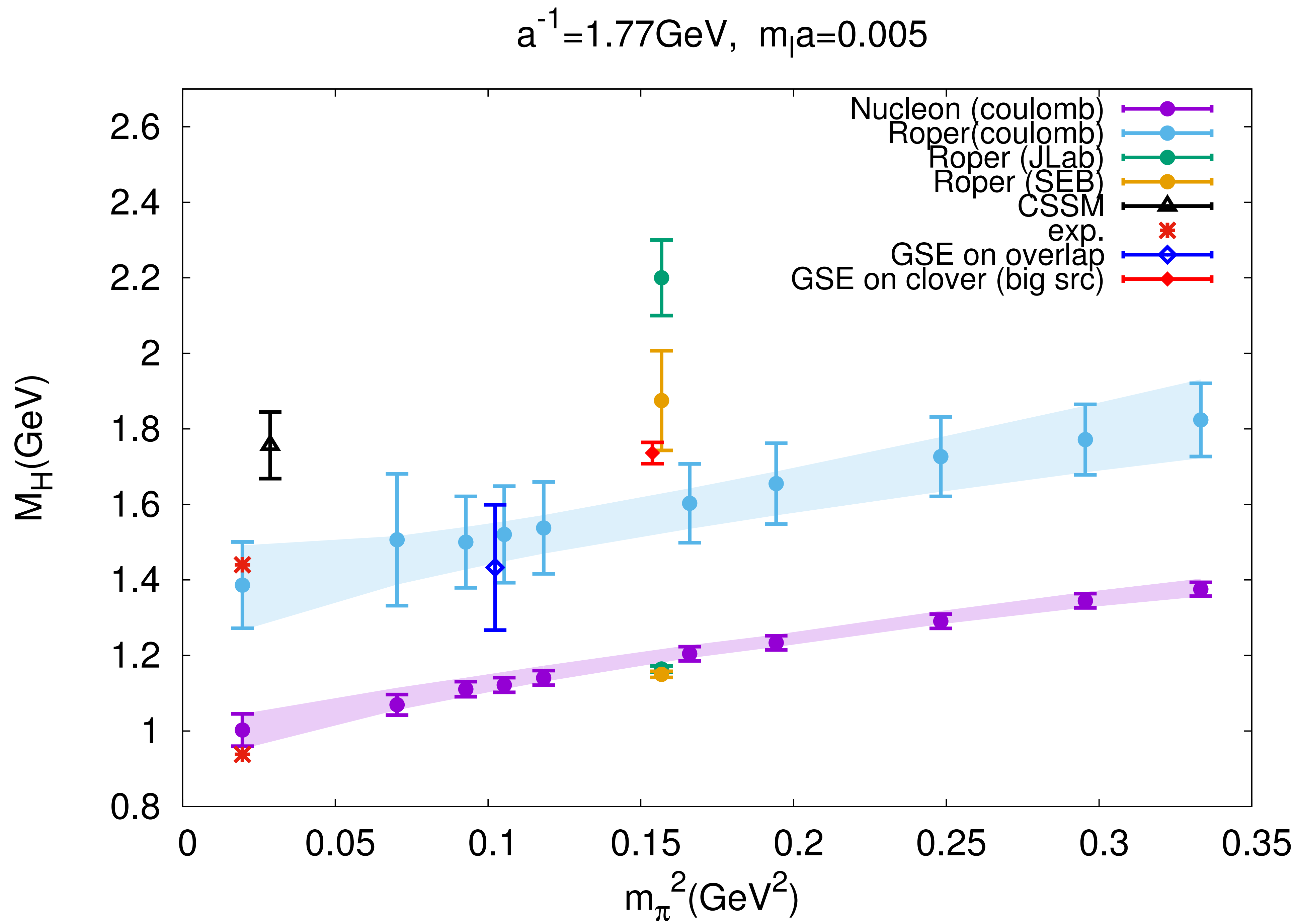
Smeared source (RMS $r \approx$ 1.1 fm), point sink



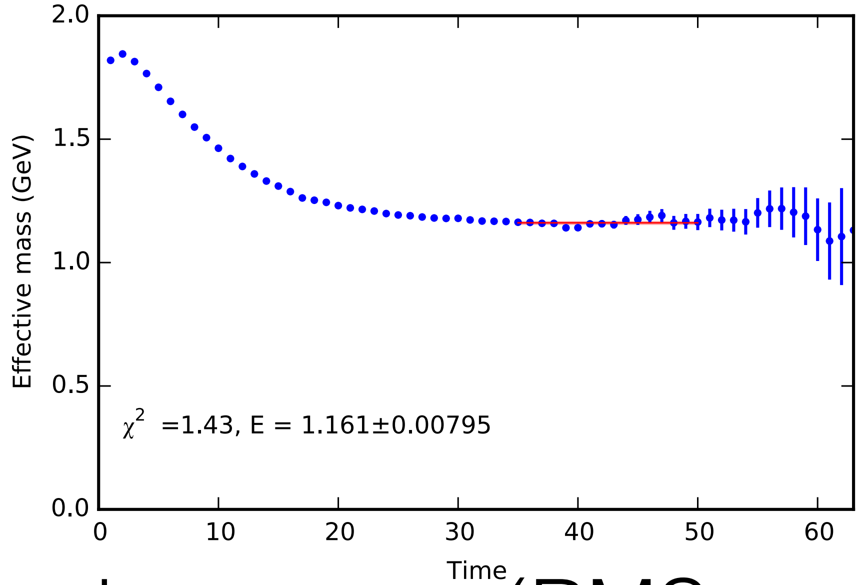
Smeared source (RMS $r \approx$ 0.62 fm), point sink

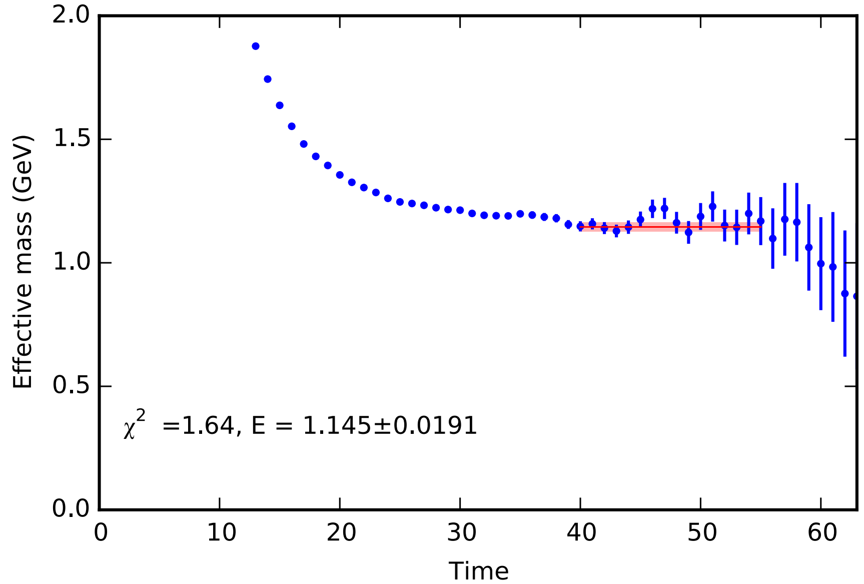






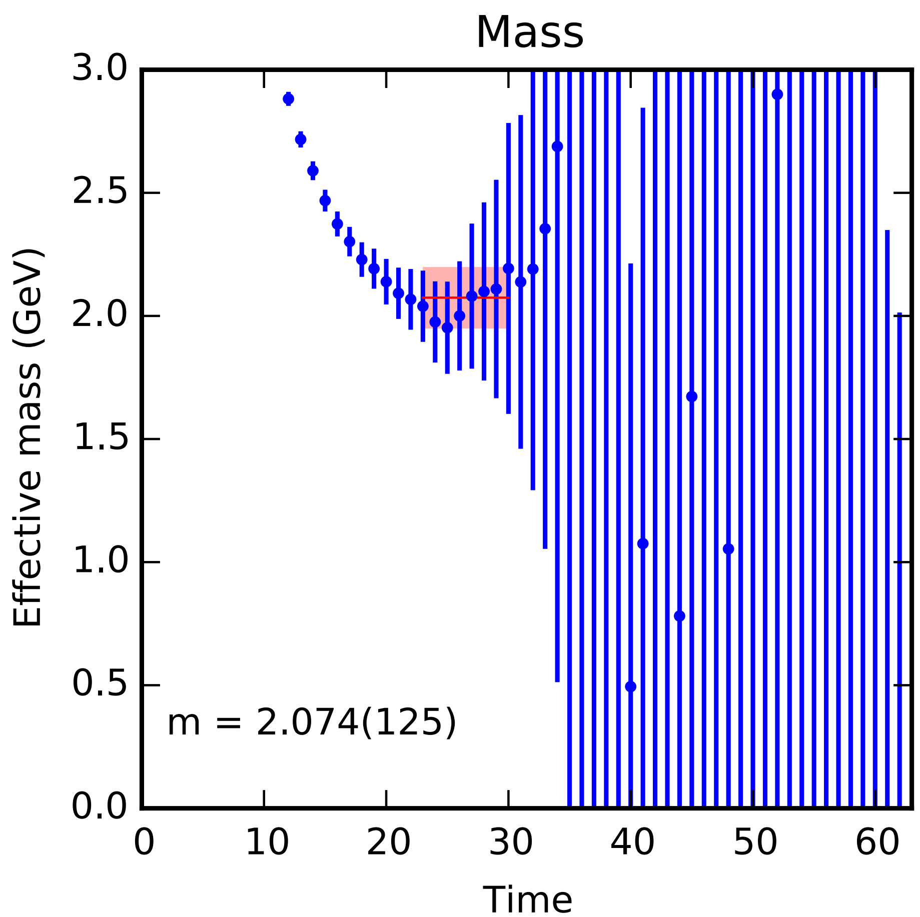
a^-1=1.77GeV, m_l a=0.005
Nucleon (coulomb)
Roper(coulomb)
Roper (JLab)
Roper (SEB)
CSSM
exp.
GSE on overlap
GSE on clover (big src)
M_H(GeV)
m_π^2(GeV^2)
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35

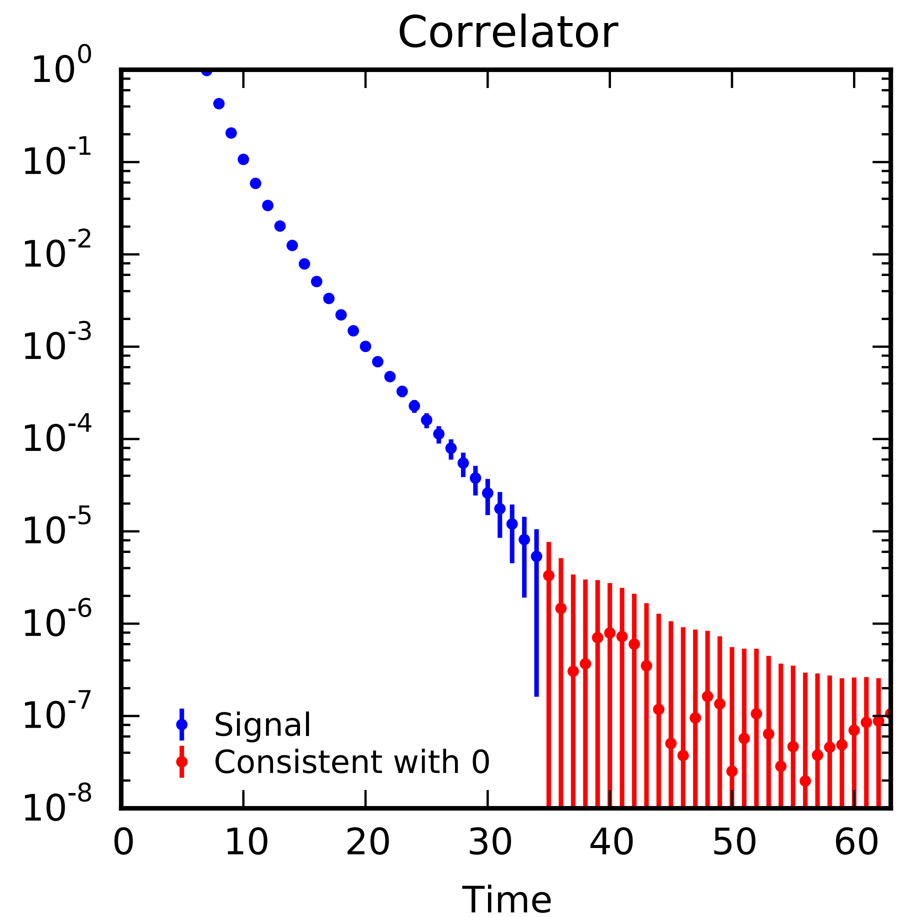


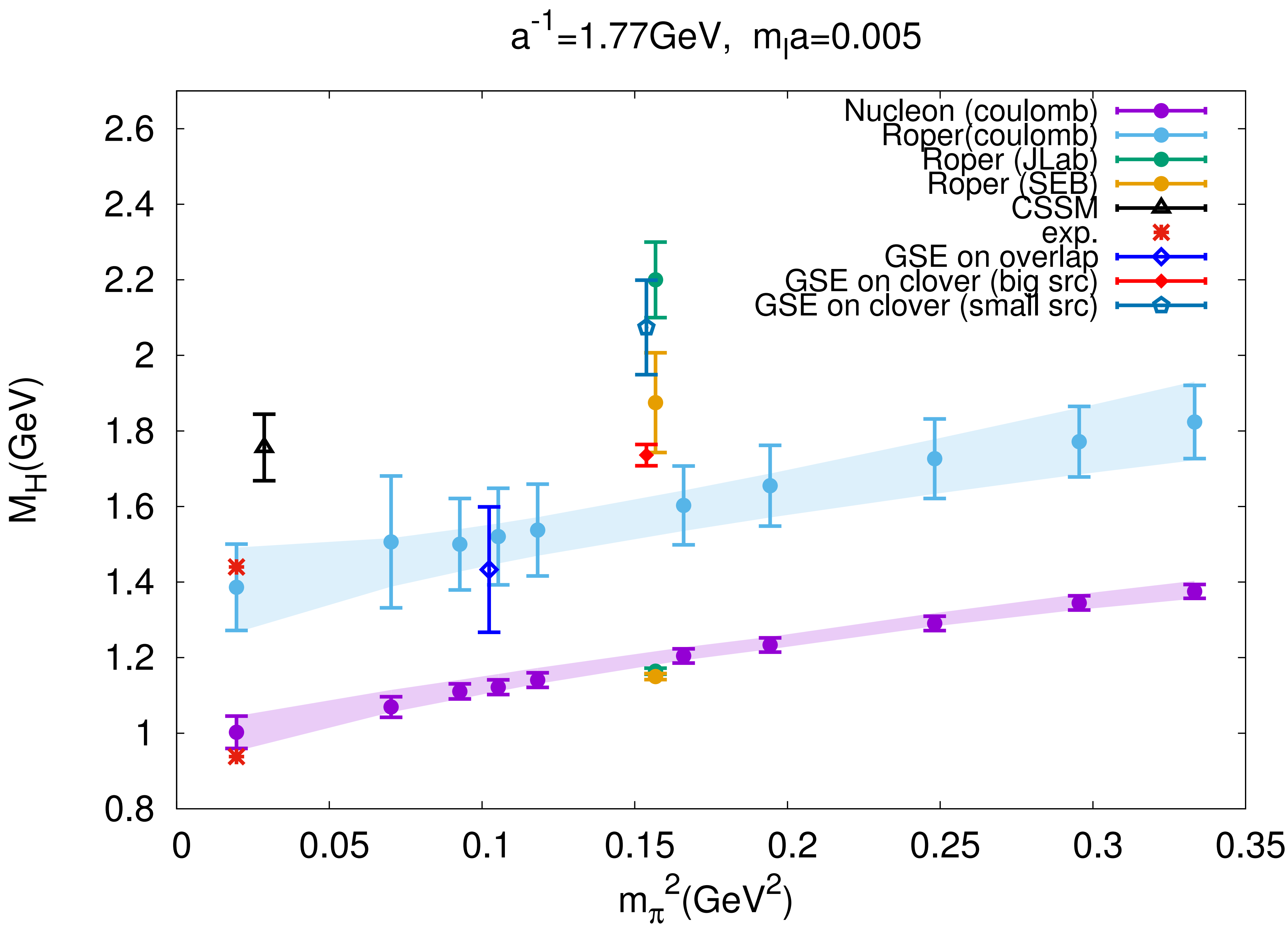


Smeared source (RMS $r \approx$ 0.32 fm), point sink

Point source, point sink



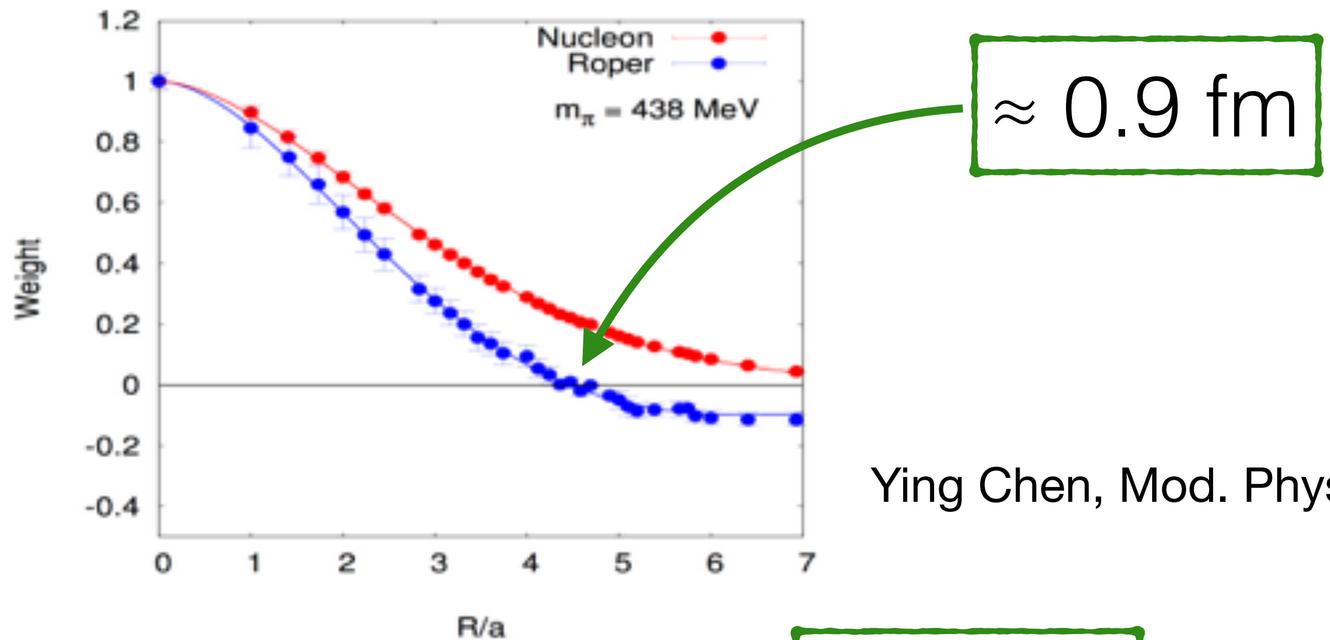




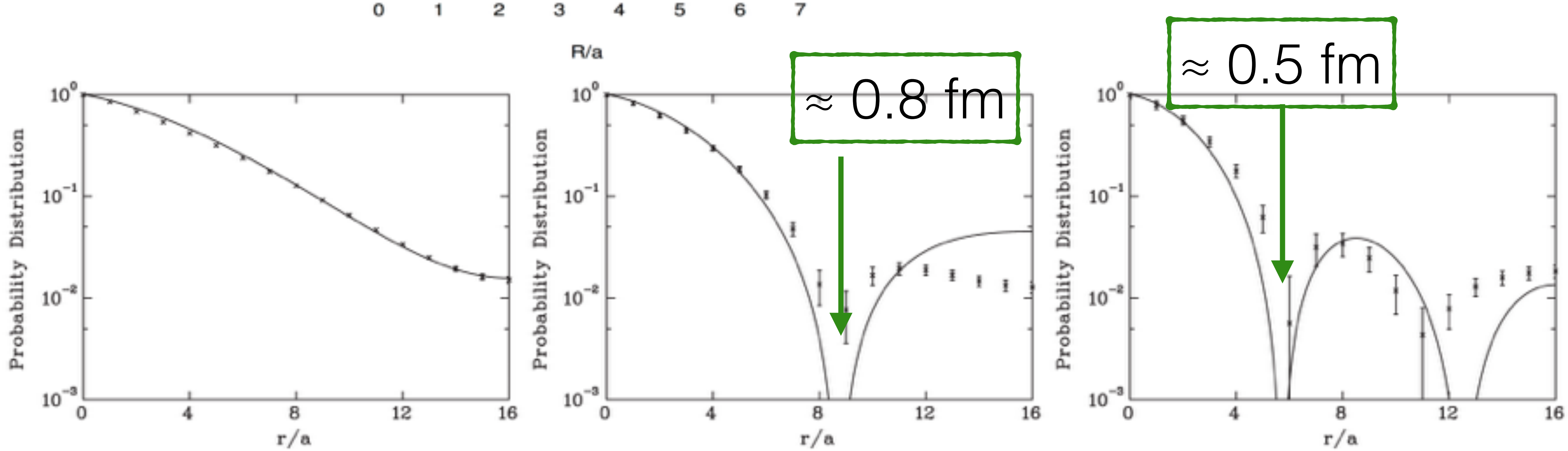
a^{-1}=1.77GeV, $m_l a$=0.005
Nucleon (coulomb)
Roper(coulomb)
Roper (JLab)
Roper (SEB)
CSSM
exp.
GSE on overlap
GSE on clover (big src)
GSE on clover (small src)
M_H(GeV)
m_π^2(GeV^2)
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35

Cause of Discrepency

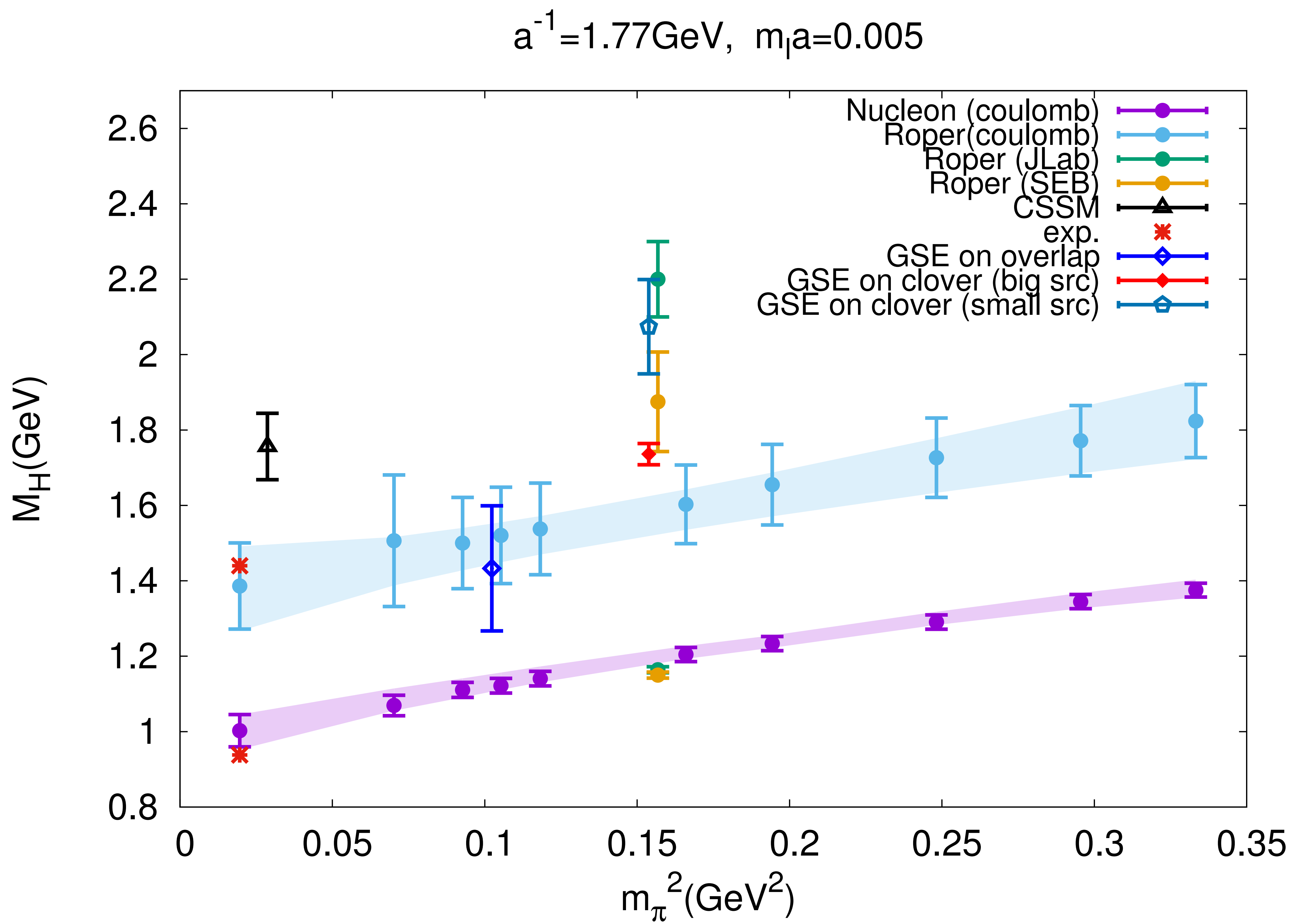
Size of operator. Source should cover node of roper wave function.



Ying Chen, Mod. Phys. Lett. **A22**, 583 (2007)

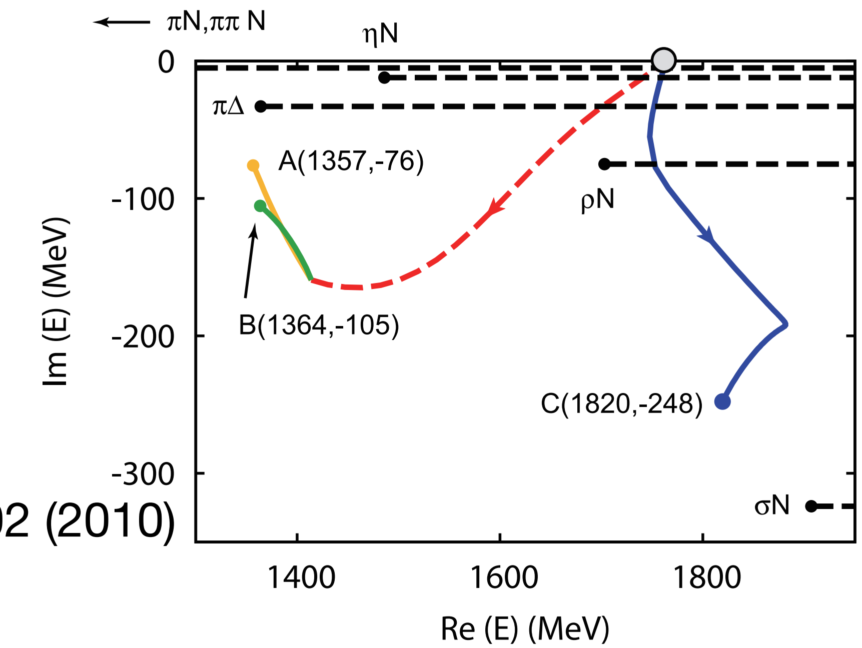


Dale S. Roberts et al. (CSSM), PRD **89**, 074501 (2014)



a^-1=1.77GeV, m_l a=0.005
Nucleon (coulomb)
Roper(coulomb)
Roper (JLab)
Roper (SEB)
CSSM
exp.
GSE on overlap
GSE on clover (big src)
GSE on clover (small src)
M_H(GeV)
m_π^2(GeV^2)
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35

Roper couples strongly to πN state.

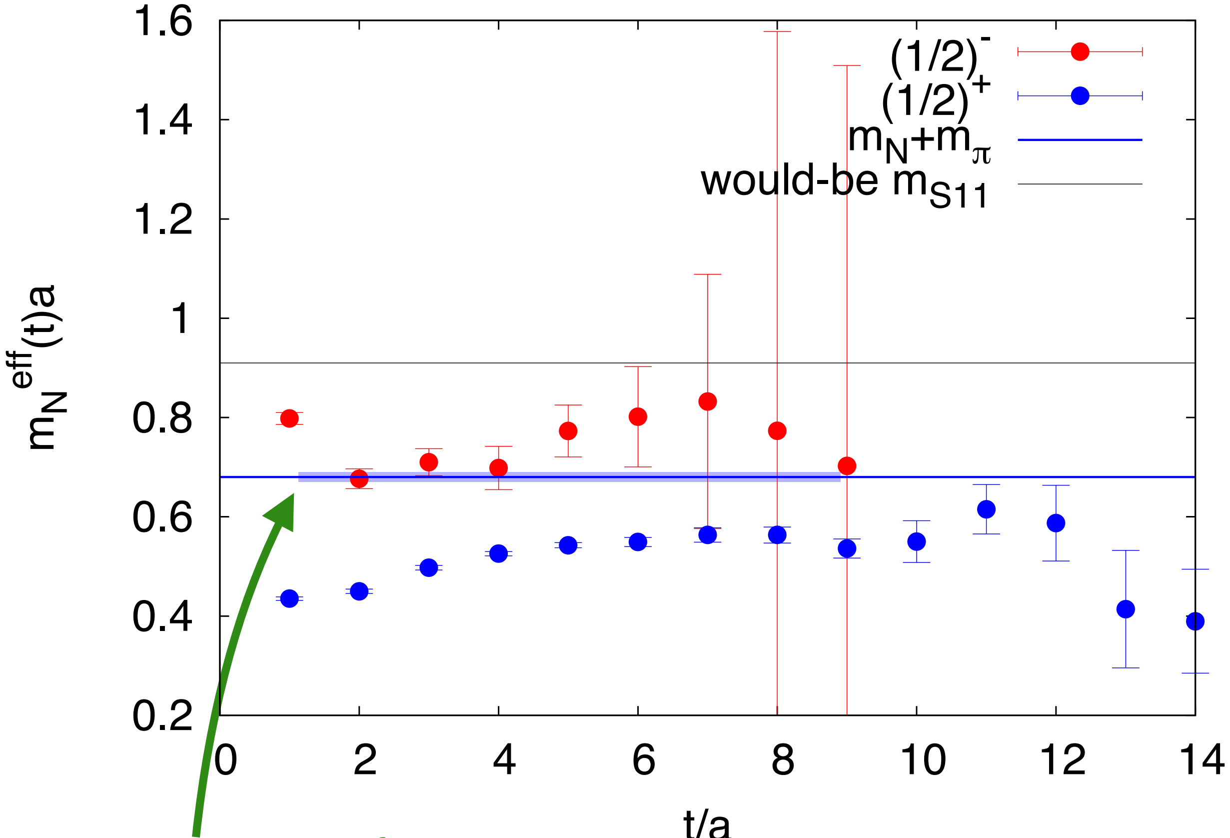


“Meson cloud effect”

B. Juliá-Díaz et al., PRC **80**, 025207 (2009)

Naomichi Suzuki et al. PRL **104**, 042302 (2010)

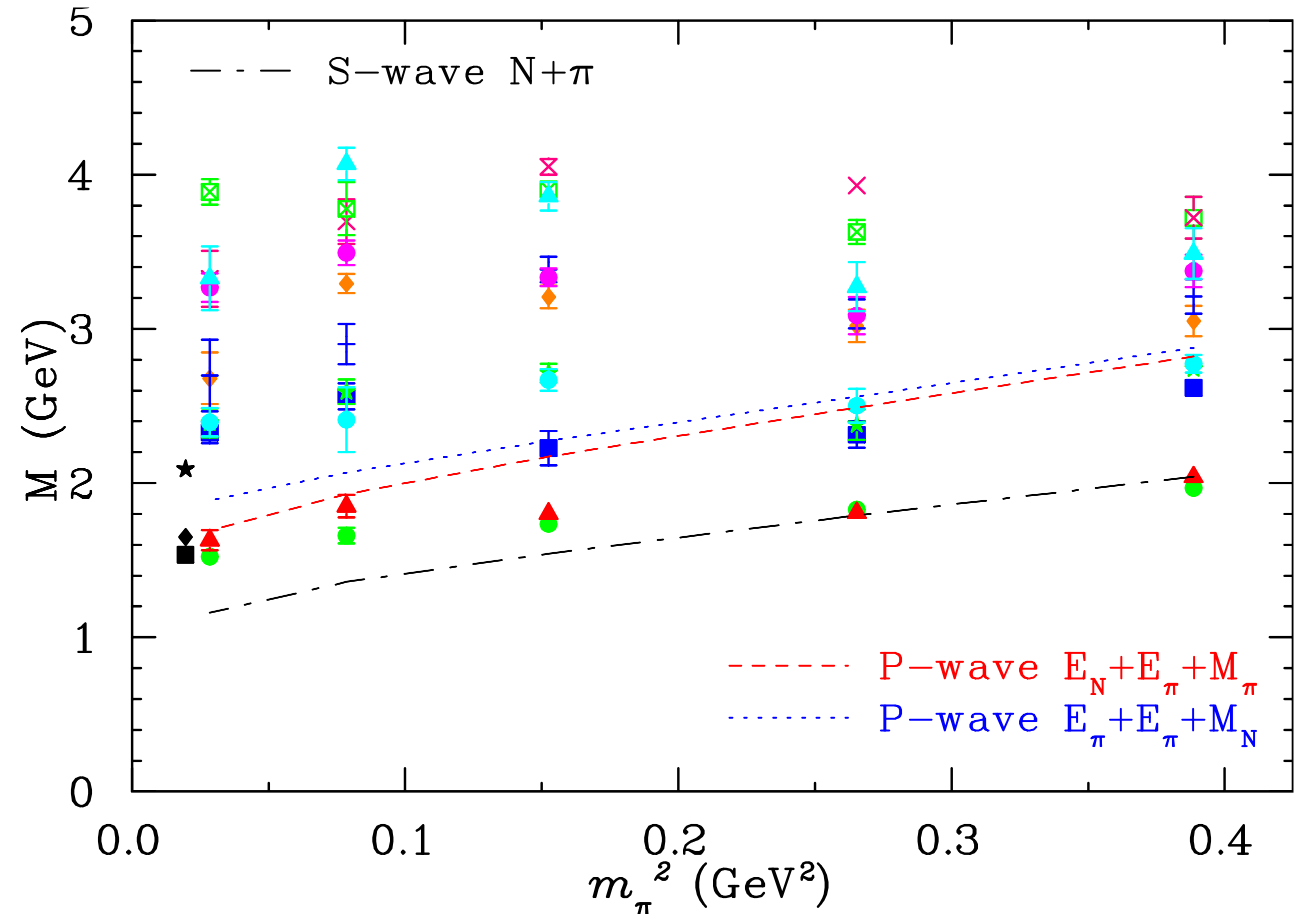
RBC/UKQCD $48^3 \times 96$ domain wall w/ overlap



1.19 GeV

Sea $m_\pi \approx 139$ MeV

Valence $m_\pi \approx 208$ MeV



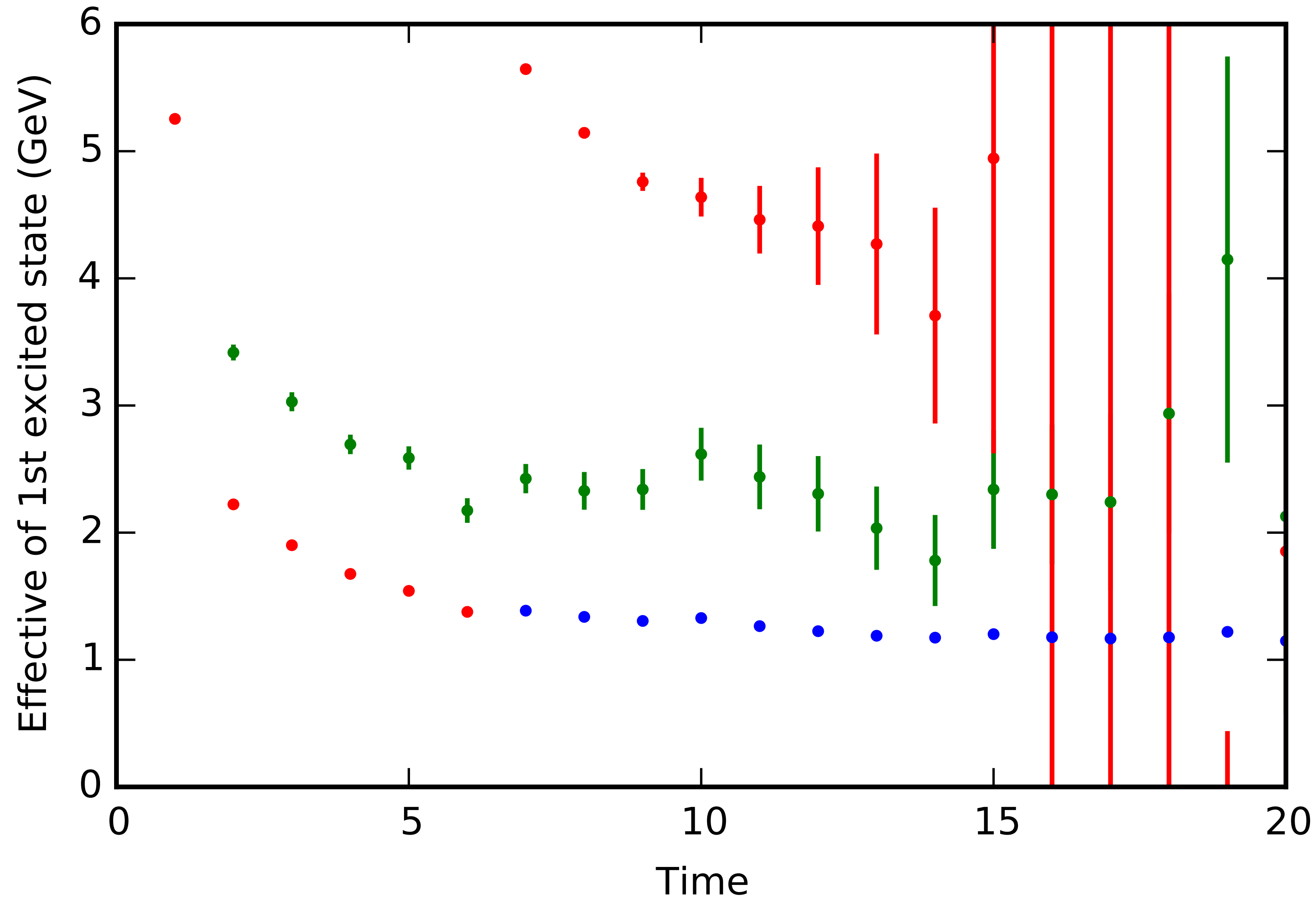
M. Selim Mahbub et al., PRD **87** 094506 (2013)

Summary

- We used GSE method to extract the mass of roper
- The roper extracted is sensitive to the size of the operator. One needs a set of large sources.
- We speculate that the πN state coupling to the 3-quark interpolation field is important.
- Effective in terms of statistics
- I invite you to try this method on your data.

Variation Method

Most studies use this approach, with multiple smear sizes, and interpolation fields.



Anisotropic clover