First Applications of the Stochastic LapH method in Lattice QCD Spectroscopy

Speaker: Chik Him Wong[*]

Authors:
Colin Morningstar[*], *Chik Him Wong*[*],
Justin Foley[*], *John Bulava*[+], *David Lenkner*[*],
Mike Peardon[−], *Keisuke Juge*[$]

(Hadron Spectrum Collaboration)
[*]Carnegie Mellon University, [+]Deutsches Elektronen Synchrotron,
[−]Trinity College, [$]University of the Pacific

Lattice 2010

Outline

- Objectives
- Reviews
  - Stochastic LapH Method
  - Simulation Details
- First Applications
  - Applications on Connected 2-pt Correlators
    - Nucleon N
    - Pion π
  - Applications on Disconnected Diagrams in Isoscalars
    - Isoscalar Psuedoscalar η
    - Isoscalar Scalar σ
  - Application on Multihadron Diagrams
    - $\pi\pi \to \pi\pi$ Correlator
    - $\rho \to \pi\pi$ Decay
- Current Work & Future Plans

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- Main Goal: Compute the Hadron Spectrum that includes Isoscalar and Multihadron states
- Via Applications of the Stochastic Laplacian Heaviside(LapH) method on a variety of Diagrams, we can:
  - Verify the feasibility & capability of the innovative method
  - Determine the dilution schemes to be used in current & future runs
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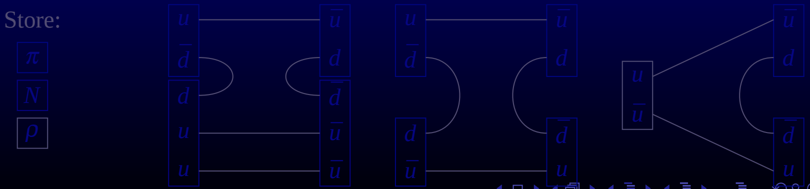
Stochastic LapH Method

- Stochastic estimation of "Distillation" perambulator M^{-1} by introducing $Z_N = e^{i2\pi n/N}$ noises ρ in Time$\times$ Spin $\times$ LapH Subspace improved with "Dilution" technique:
$$M\varphi_D = P^{[D]}\rho, \sum_D E(P^{[D]}\rho(P^{[D]}\rho)^*) = 1 \to M^{-1} = \sum_D E(\varphi_D(P^{[D]}\rho)^*)$$
- Expected Advantages:
  - Suppressed High-lying mode contamination due to the LapH projection
  - Number of Inversions stays almost constant for any lattice size V for a given maximum cutoff eigenvalue due to Dilution technique
  - Factorization into Single Hadron Operators provides a convenient way of constructing different diagrams without storage of huge perambulators:



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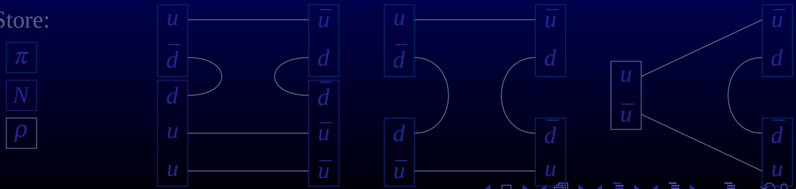

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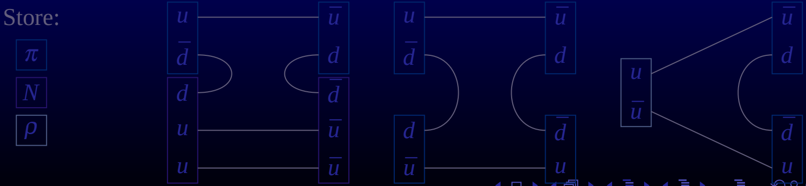

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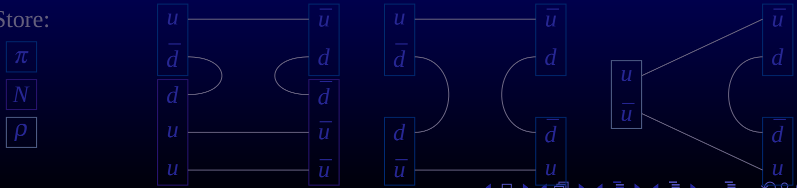

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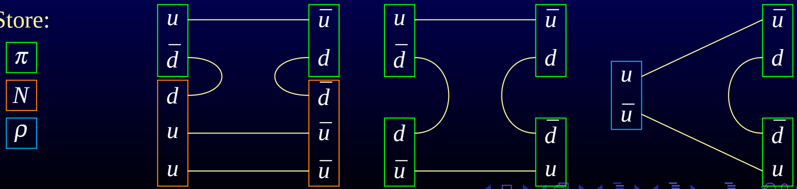

Simulation Details

- Action:
  - Anisotropic Clover Action
  - Symanzik Improved Gauge Action
  - $a_s/a_t = 3.5$, $a_s = 0.12$ fm
- Available and relevant gauge configurations:

m_π(MeV)	m_{q_l}	Lattice Size($N_x^3 \times N_t$)	N_f	
380	-0.0840	$16^3 \times 128$	$2+1$	First Application
360	-0.0840	$24^3 \times 128$	$2+1$	Current Work
220	-0.0860	$24^3 \times 128$	$2+1$	Current Work
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- Selected Dilution Schemes:
  - Z_4 Noise

Dilution Subspace	t_0-t Propagator	t-t Propagator
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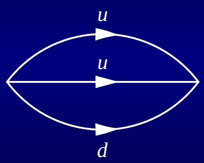

- Connected Diagram
- 3 Noises, $1t_0$
- 52 configs
- $V = 16^3 \times 128$, 32 Laplacian Eigenvectors

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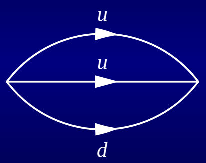

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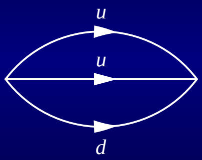

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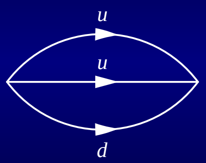

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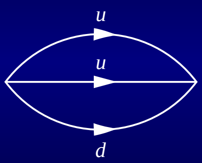

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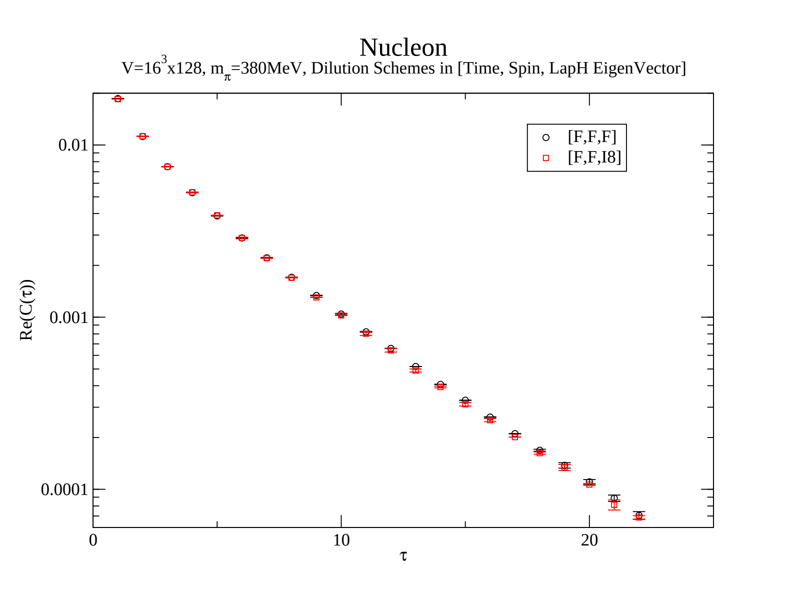
Applications on Connected 2-pt Correlators: N



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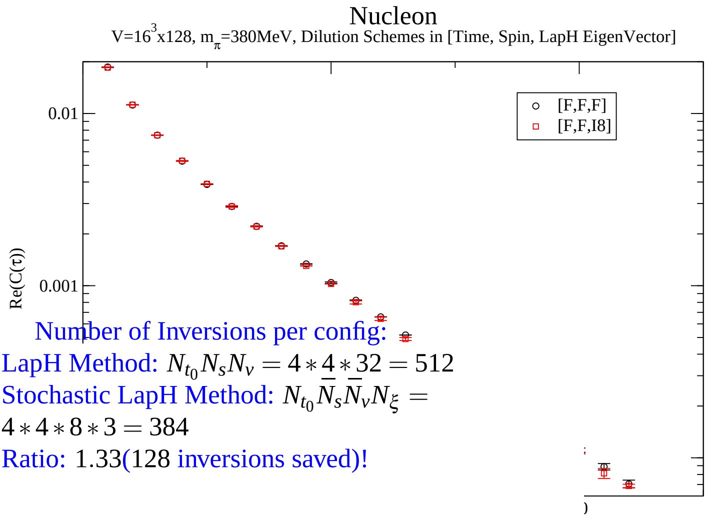


Number of Inversions per config:

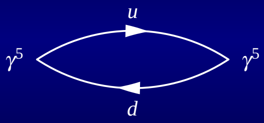
LapH Method: $N_{t_0} N_s N_v = 4 * 4 * 32 = 512$

Stochastic LapH Method: $N_{t_0} \overline{N}_s \overline{N}_v N_\xi = 4 * 4 * 8 * 3 = 384$

Ratio: 1.33(128 inversions saved)!

Applications on Connected 2-pt Correlators

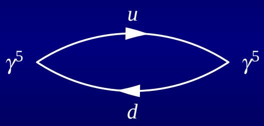
- Pion π :



- Connected Diagram
- 2 Noises, $1t_0$
- 52 configs
- $V = 16^3 \times 128$, 32 Laplacian Eigenvectors

Applications on Connected 2-pt Correlators

- Pion π :



- Connected Diagram
- 2 Noises, $1t_0$
- 52 configs
- $V = 16^3 \times 128$, 32 Laplacian Eigenvectors

Applications on Connected 2-pt Correlators

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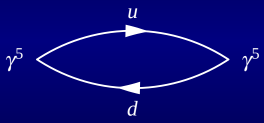

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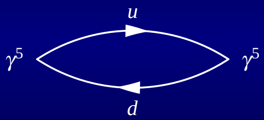

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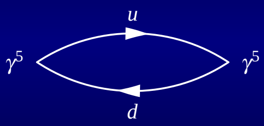

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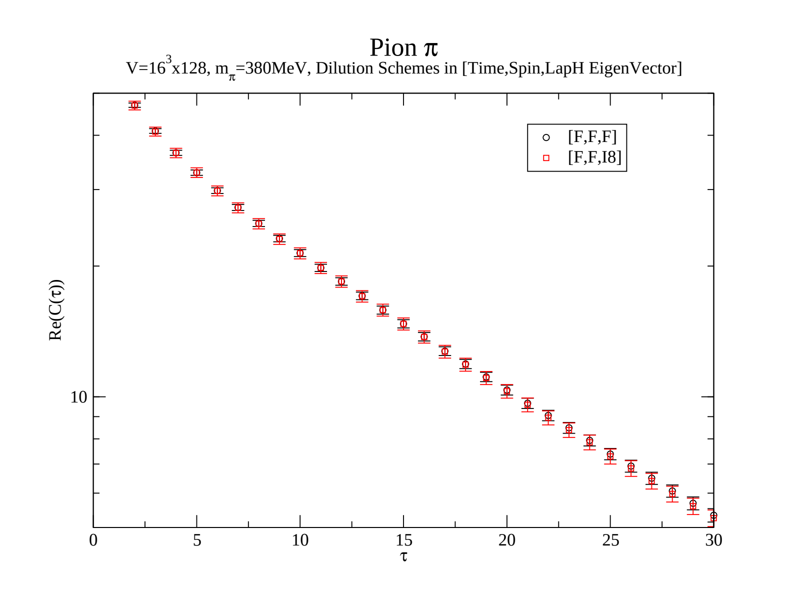

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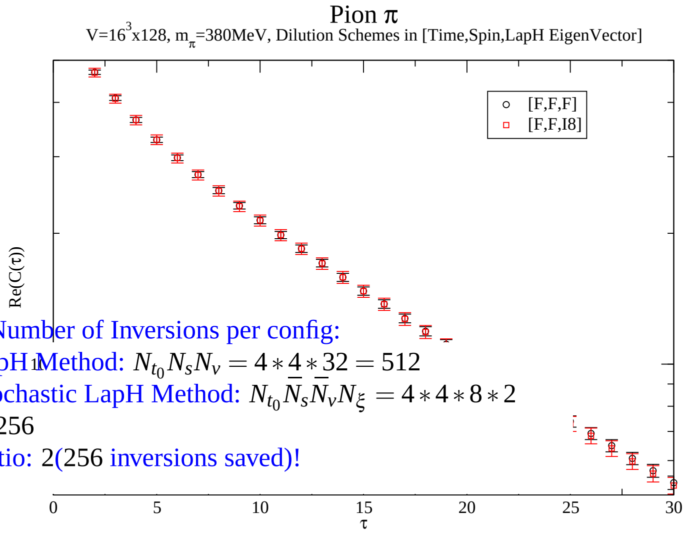


Number of Inversions per config:

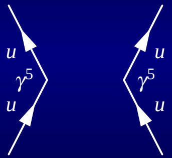
LapH Method: $N_{t_0}N_sN_v = 4*4*32 = 512$

Stochastic LapH Method: $N_{t_0}\bar{N}_s\bar{N}_vN_\xi = 4*4*8*2 = 256$

Ratio: 2(256 inversions saved)!

Applications on Disconnected Diagrams in Isoscalars

- Isoscalar Psuedoscalar η :



- Disconnected Diagram
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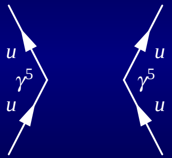
Applications on Disconnected Diagrams in Isoscalars

- Isoscalar Psuedoscalar η :



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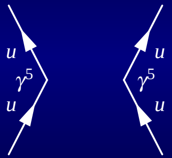

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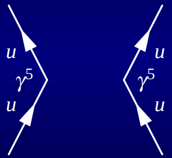

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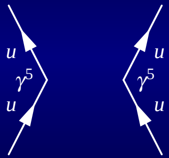

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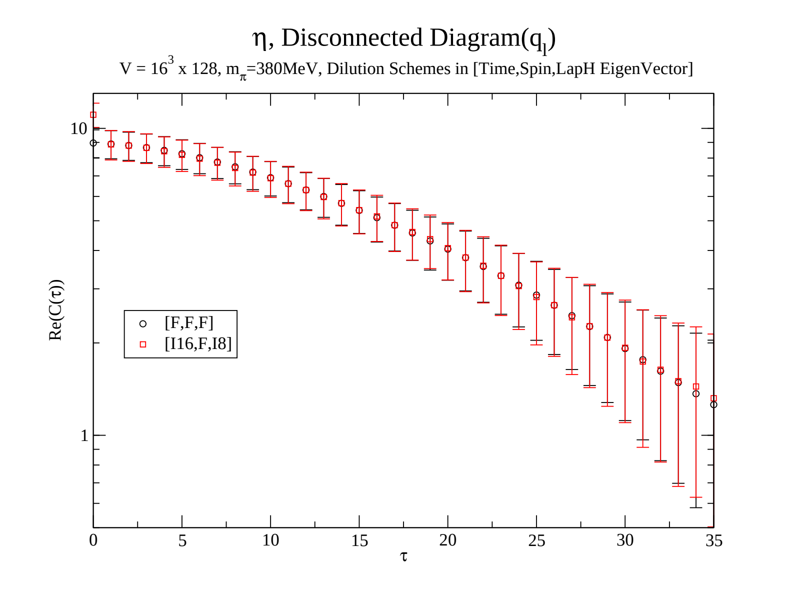

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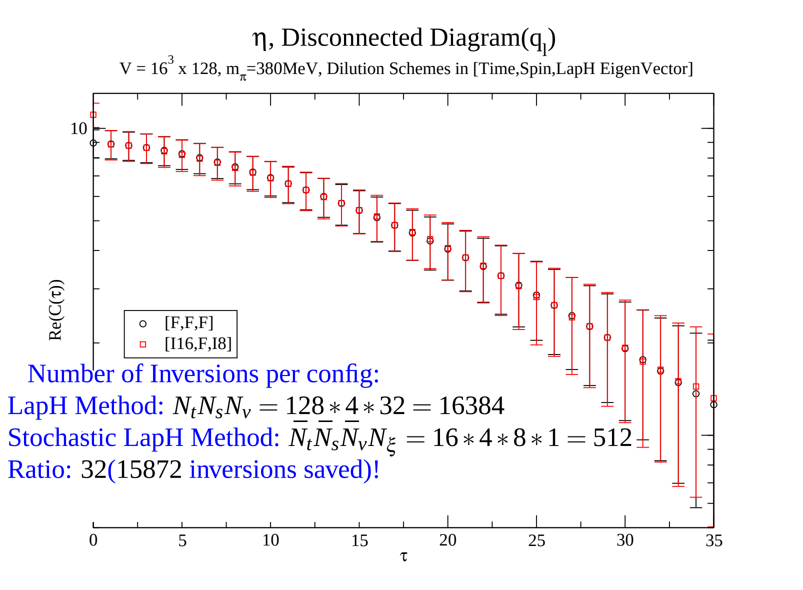

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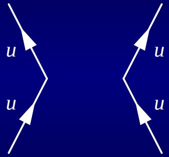
Stochastic LapH Method: $\bar{N}_t \bar{N}_s \bar{N}_v N_\xi = 16 * 4 * 8 * 1 = 512$

Ratio: 32(15872 inversions saved)!

Applications on Disconnected Diagrams in Isoscalars

- Isoscalar Scalar σ :



- Disconnected Diagram
- Vacuum Expectation Value subtracted
- 1 Noise, all t_0s
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Applications on Disconnected Diagrams in Isoscalars

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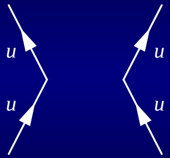

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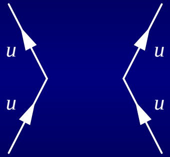

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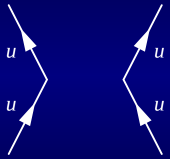

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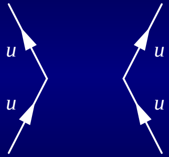

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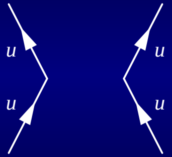

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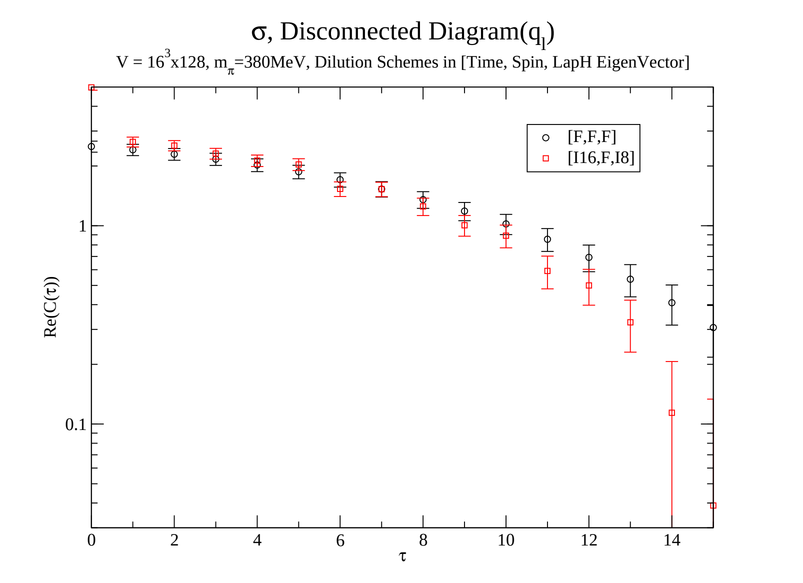
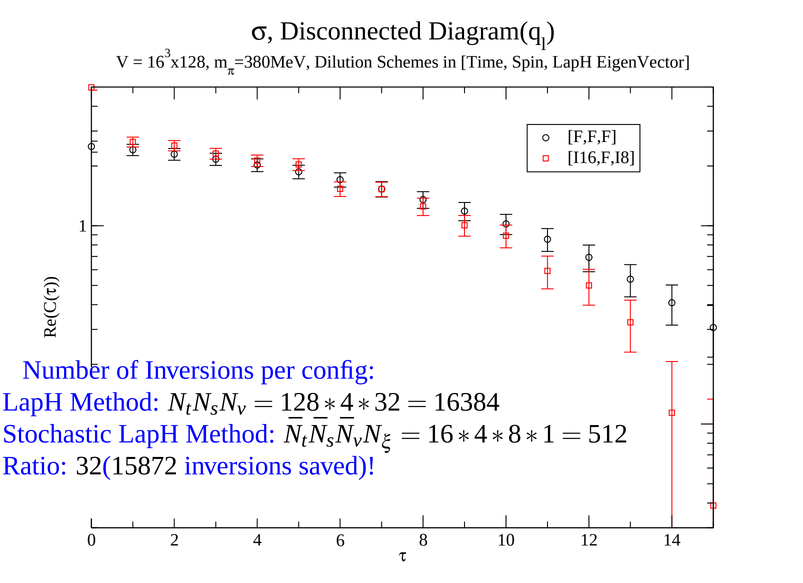


Applications on Disconnected Diagrams in Isoscalars: σ



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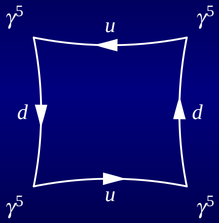
Ratio: 32(15872 inversions saved)!

Applications on Multihadron Diagrams

- $\pi\pi \rightarrow \pi\pi$ Correlator:



- Box Diagram
- 4 Noises, 4 t_0s
- 52 configs
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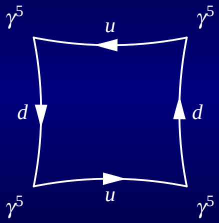
Applications on Multihadron Diagrams

- $\pi\pi \to \pi\pi$ Correlator:



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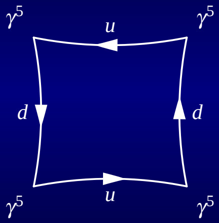

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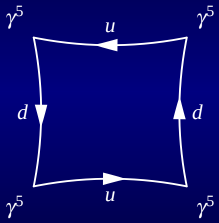

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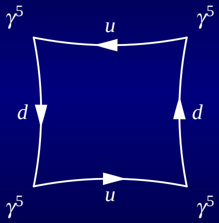

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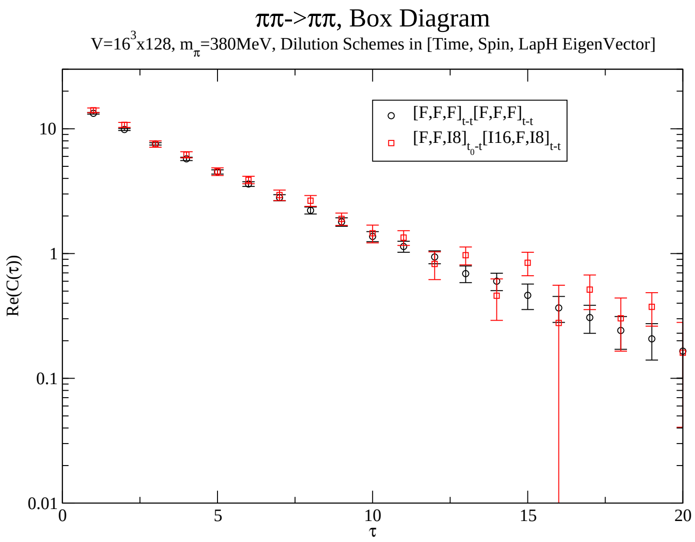

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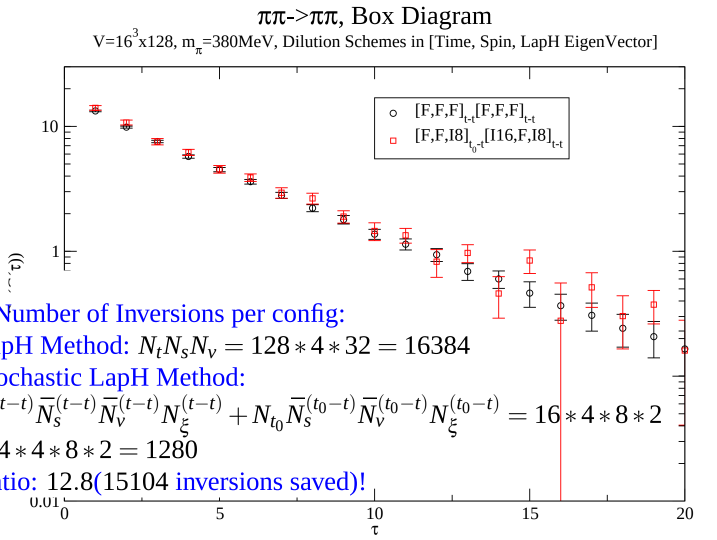

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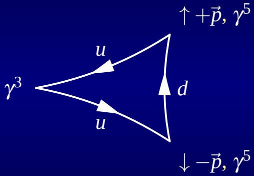
Stochastic LapH Method:

$$\overline{N}_t^{(t-t)}\overline{N}_s^{(t-t)}\overline{N}_v^{(t-t)}N_\xi^{(t-t)} + N_{t_0}\overline{N}_s^{(t_0-t)}\overline{N}_v^{(t_0-t)}N_\xi^{(t_0-t)} = 16 * 4 * 8 * 2$$
$$+ 4 * 4 * 8 * 2 = 1280$$

Ratio: 12.8(15104 inversions saved)!

Applications on Multihadron Diagrams

- $\rho \to \pi\pi$ Decay :



- Triangle Diagram
- $\vec{p} = (0,0,1)$
- 2 sets of 3 Noises, 4 t_0s each set
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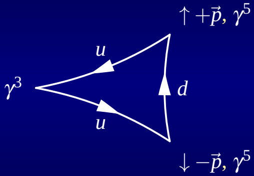
Applications on Multihadron Diagrams

- $\rho \to \pi\pi$ Decay :



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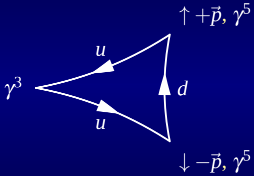

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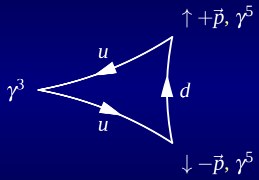

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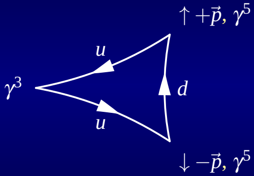

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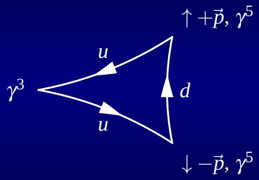

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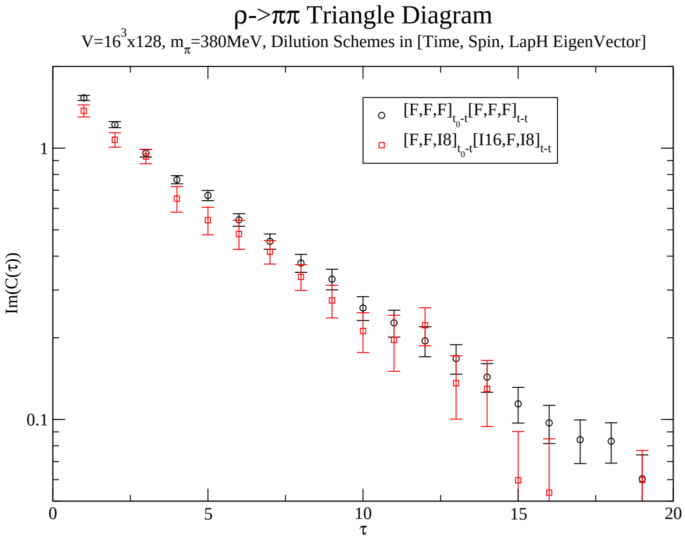

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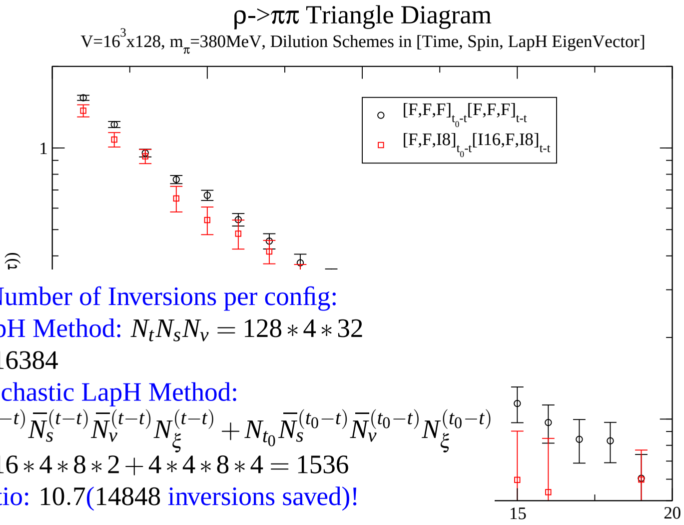

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$= 16 * 4 * 8 * 2 + 4 * 4 * 8 * 4 = 1536$

Ratio: 10.7(14848 inversions saved)!

Current Work & Future Plans

- Summary
  - The Stochastic LapH method provides a promising approach for multihadron & isoscalar calculations
  - The Stochastic LapH method saves a lot of work compared with the LapH method
  - $V = 16^3$: It is an alternative; Larger volumes: Ordinary LapH is not possible!
- Current Work
  - Generation of Quark Sources and Sinks
  - Generation of Hadron "Source"s and "Sink"s
  - Gauge Configurations used:

m_π(MeV)	m_{q_l}	Lattice Size($N_x^3 \times N_t$)	N_f
360	-0.0840	$24^3 \times 128$	$2+1$
220	-0.0860	$24^3 \times 128$	$2+1$
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Q & A