# High precision scale setting

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BMW collaboration

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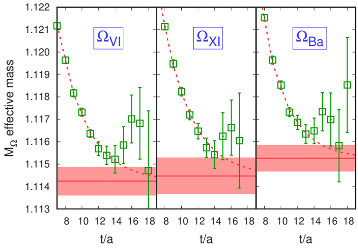
SFB TR55

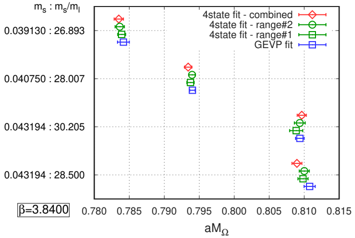
# Extraction of the Ω mass:




Three different operators:

- VI and XI from [1]
- Ba from [2]

→ VI for main analysis




Two methods for mass extraction:

- 4 state fits with priors
- GEVP based [3] approach

Results from different fit ranges and methods agree well.


[1] M. F. L. Golterman and J. Smit, "Lattice Baryons With Staggered Fermions," Nucl. Phys. B **255** (1985), 328-340 doi:10.1016/0550-3213(85)90138-5

[2] J. A. Bailey, "Staggered baryon operators with flavor SU(3) quantum numbers," Phys. Rev. D **75** (2007), 114505 doi:10.1103/PhysRevD.75.114505 [arXiv:hep-lat/0611023 [hep-lat]].

[3] C. Aubin and K. Orginos, "A new approach for Delta form factors," AIP Conf. Proc. **1374** (2011) no.1, 621-624 doi:10.1063/1.3647217 [arXiv:1010.0202 [hep-lat]].

## Extraction of the $\Omega$ mass:

### 4 state fit extraction

Fit propagator to

$$H(t; A, M) = A_1 h_+(t; M_0) + A_1 h_-(t; M_1) + A_2 h_+(t; M_2) + A_3 h_-(t; M_3)$$

with $h_+(t, M) = e^{-Mt} + (-1)^{t-1} e^{-M(t-T)}$ and $h_-(t, M) = -h_+(T - t, M)$.

Use priors for the excited state masses:

| prior mean | rel. prior width |
|---|---|
| 2012 MeV | 0.10 |
| 2250 MeV | 0.10 |
| 2400 MeV | 0.15 |

### GEVP based extraction

Construct matrix from folded propagator $H_t$:

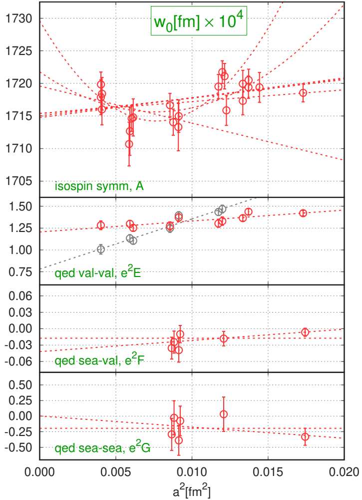
$$\mathcal{H}(t) = \begin{pmatrix} H_{t+0} & H_{t+1} & H_{t+2} & H_{t+3} \\ H_{t+1} & H_{t+2} & H_{t+3} & H_{t+4} \\ H_{t+2} & H_{t+3} & H_{t+4} & H_{t+5} \\ H_{t+3} & H_{t+4} & H_{t+5} & H_{t+6} \end{pmatrix}$$

and solve $\mathcal{H}(t_a) v(t_a, t_b) = \lambda(t_a, t_b) \mathcal{H}(t_b) v(t_a, t_b)$.

Then, extract mass from $C(t) = v^\dagger(t_a, t_b) \mathcal{H}(t) v(t_a, t_b)$ between $t_0$ and $t_1$.

No assumption on the masses of the excited states.

## $w_0$ from $\Omega$ mass:




$$w_0 = 0.17236(29)(63)[70]\,\mathrm{fm}$$

Using Type I fit:

$$w_0 M_\Omega = A + BX_l + CX_s + Ee_v^2 + FXe_v e_s + Ge_s^2$$

with

$$X_l = M_{\pi^0}^2/M_\Omega^2 - \left[M_{\pi^0}^2/M_\Omega^2\right]_*$$

$$X_s = M_{K_\chi}^2/M_\Omega^2 - \left[M_{K_\chi}^2/M_\Omega^2\right]_*$$

$$M_{K_\chi}^2 = \frac{1}{2}(M_{K^0}^2 + M_{K^+}^2 - M_{\pi^+}^2)$$

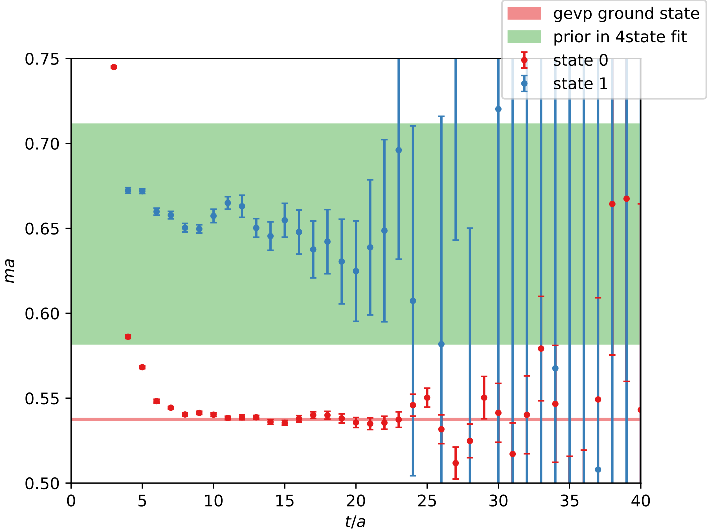
Error by histogram method:

- Flat weight between for fits with different datapoints
- AIC weight for fits with the same data points

Isospin splitting condtributions via chain rule or finite differences from $\mathcal{M}[\langle H\rangle]$.

**backup slides**

# 4 state fit priors vs. GEVP excited states



## Isospin splitting contributions

$$M_0 = \mathcal{M}[\langle H_0\rangle_0]$$

$$M''_{02} = \frac{\delta\mathcal{M}[H]}{\delta H}\bigg|_{\langle H_0\rangle_0}\langle H\rangle''_{02} = \frac{\delta\mathcal{M}[H]}{\delta H}\bigg|_{\langle H_0\rangle_0}\left\langle (H_0 - \langle H_0\rangle_0)\frac{\mathrm{dets}''_2}{\mathrm{dets}_0}\right\rangle$$

$$M''_{20} \approx \frac{1}{e_v^2}(\mathcal{M}[\frac{1}{2}\langle H_+ + H_-\rangle_0] - \mathcal{M}[\langle H_0\rangle_0])$$

$$M''_{11} \approx \frac{\delta\mathcal{M}[H]}{\delta H}\bigg|_{\langle H_+ + H_-\rangle_0}\left\langle \frac{H_+ - H_-}{2e_v}\frac{\mathrm{dets}'_1}{\mathrm{dets}_0}\right\rangle_0$$

$$M'_m \approx \frac{m_l}{\delta m}(\mathcal{M}[\langle H_{\delta m}\rangle_0] - \mathcal{M}[\langle H_0\rangle_0])$$