High-momentum tails and low-momentum effective theories

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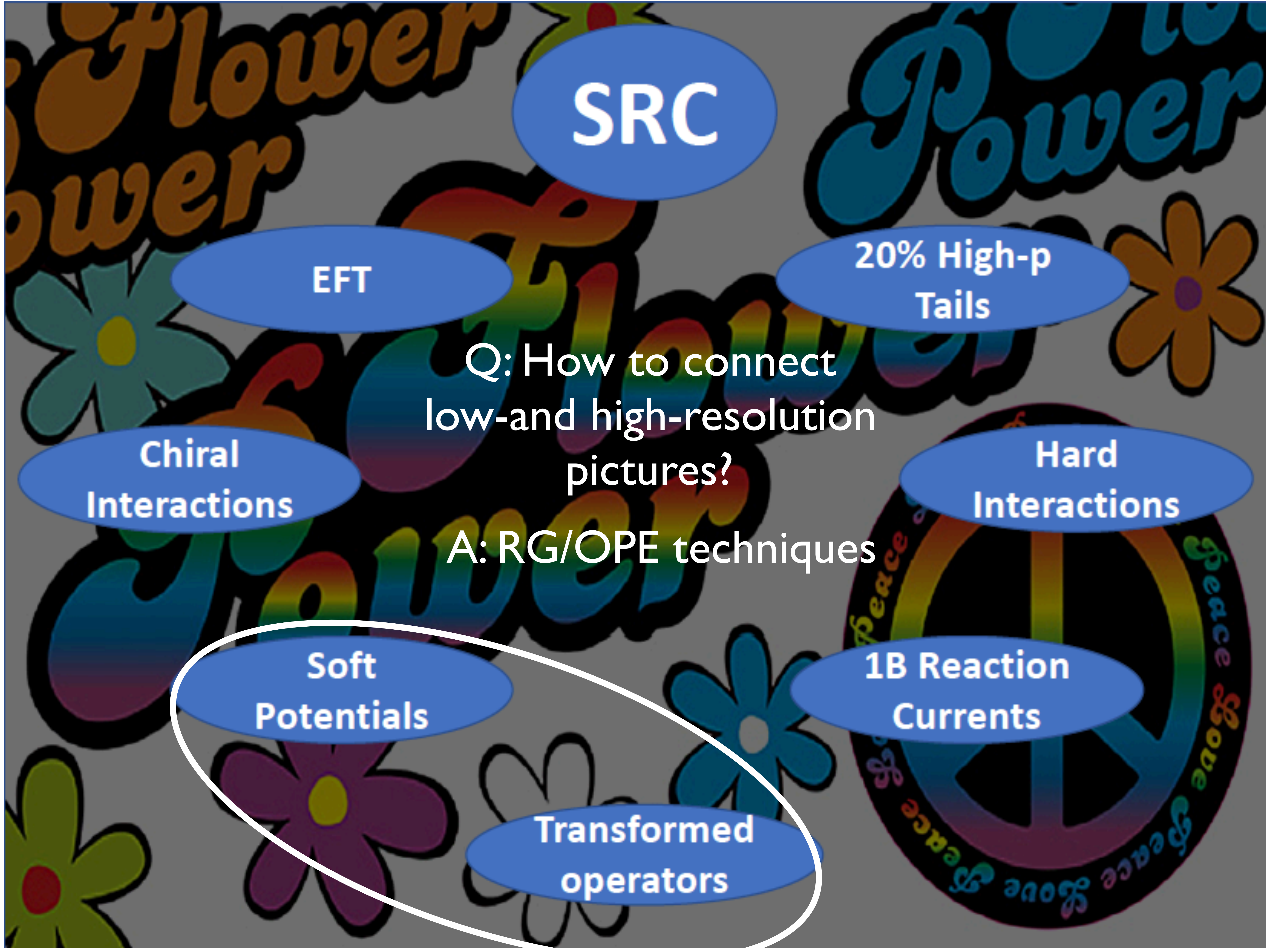
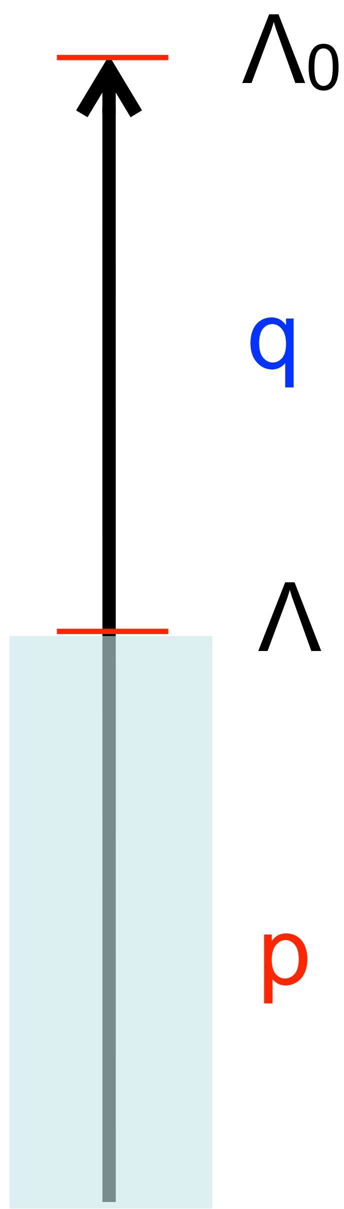

SRC
EFT
20% High-p Tails
Q: How to connect low-and high-resolution pictures?
Chiral Interactions
Hard Interactions
A: RG/OPE techniques
Soft Potentials
1B Reaction Currents
Transformed operators

High-q operators in low resolution effective theories

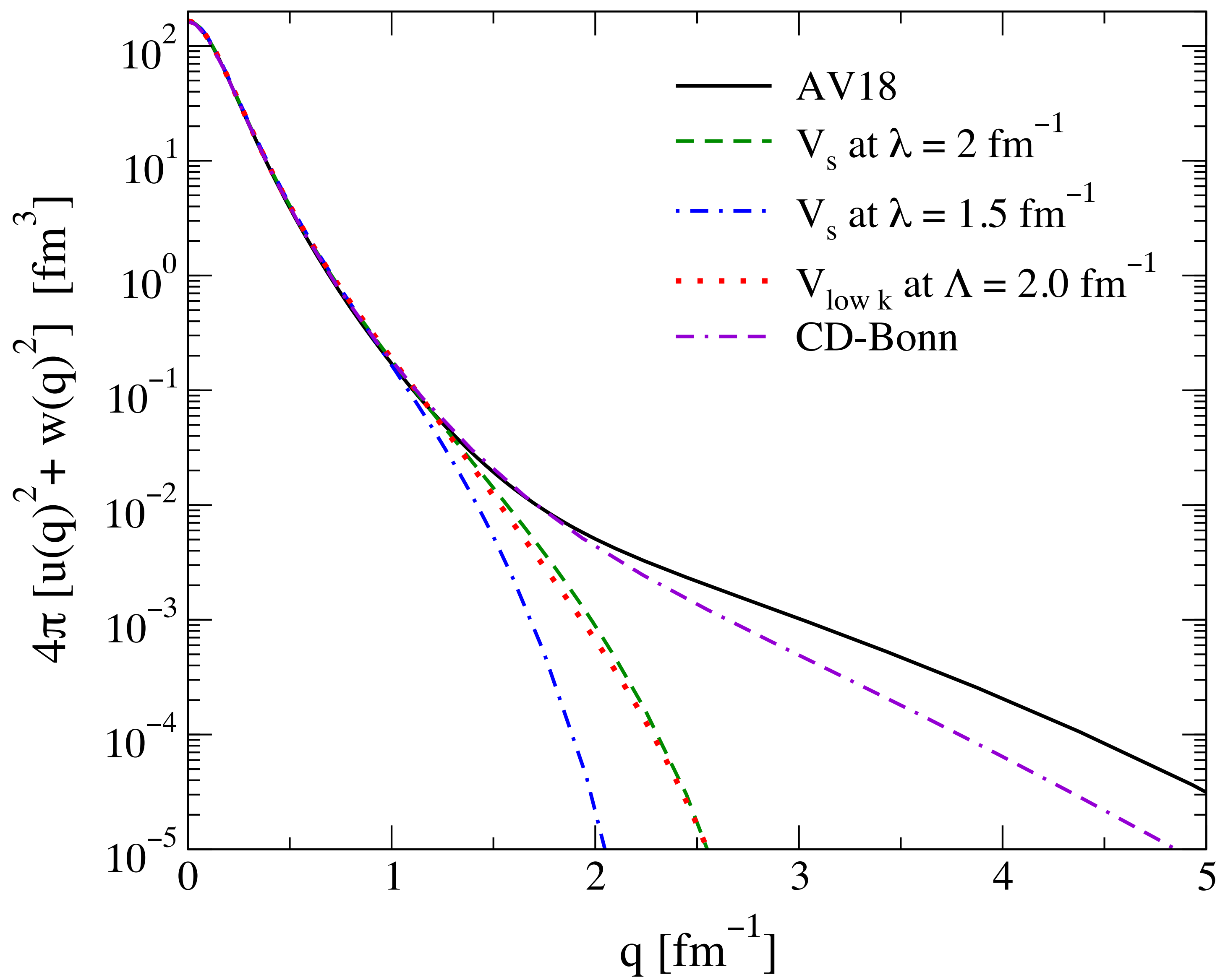
Wave function factorization and the OPE

Consider low-k components of low-E wf's for A=2.



RG preserves long distance structure

$$\psi_\alpha^{\Lambda_0}(\mathbf{p}) \approx Z_\Lambda \psi_\alpha^{\Lambda}(\mathbf{p})$$



Anderson et al., PRC **82** (2010)

SKB and Roscher, PRC **86** (2012)

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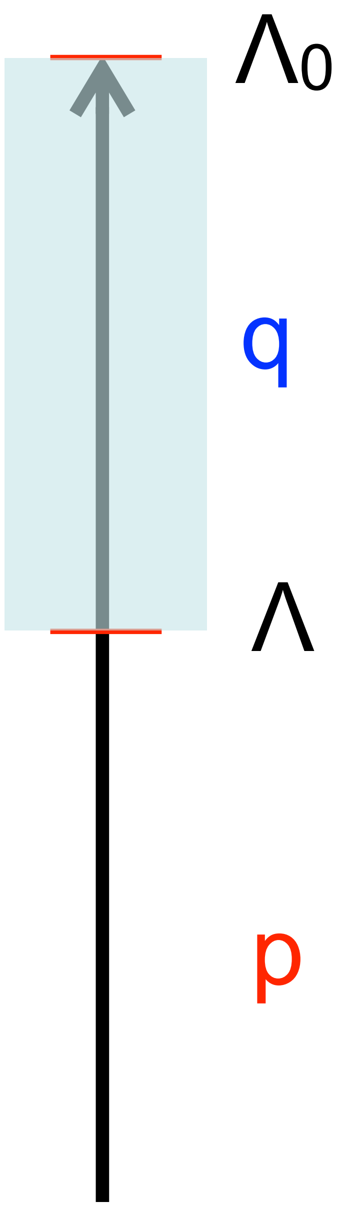

Scale separation ($E_\alpha \ll \Lambda^2 \ll q^2$)

$$\psi_\alpha^{\Lambda_0}(\mathbf{q}) \approx \gamma(\mathbf{q};\Lambda)\int_0^\Lambda d^3p\, Z_\Lambda \psi_\alpha^\Lambda(\mathbf{p}) + \eta(\mathbf{q};\Lambda)\int_0^\Lambda d^3p\,\mathbf{p}^2 Z_\Lambda \psi_\alpha^\Lambda(\mathbf{p})\cdots$$

Anderson et al., PRC **82** (2010)
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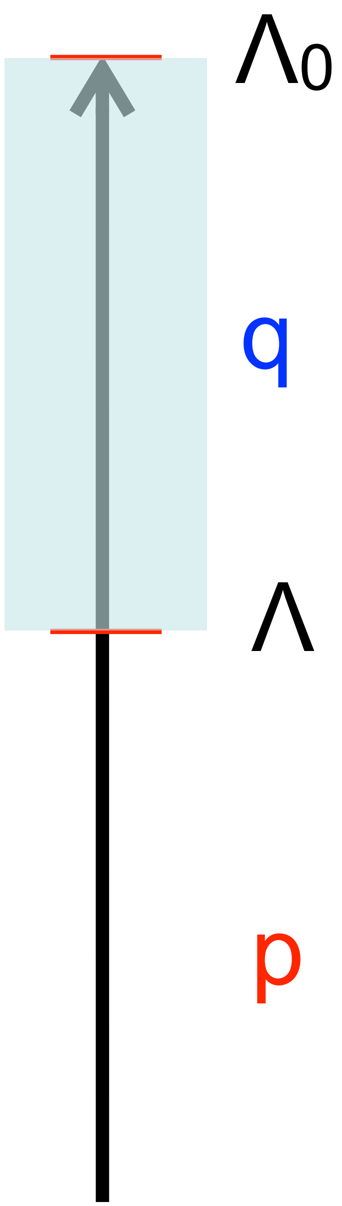


Scale separation ($E_\alpha << \Lambda^2 << q^2$)

$$\psi_\alpha^{\Lambda_0}(\mathbf{q}) \approx \gamma(\mathbf{q};\Lambda) \int_0^\Lambda d^3p\, Z_\Lambda \psi_\alpha^\Lambda(\mathbf{p}) + \eta(\mathbf{q};\Lambda) \int_0^\Lambda d^3p\, \mathbf{p}^2 Z_\Lambda \psi_\alpha^\Lambda(\mathbf{p}) \cdots$$

Operator **P**roduct **E**xpansion
of wave function a-la Lepage

$$\gamma(\mathbf{q};\Lambda) = -\int_\Lambda^{\Lambda_0} d\mathbf{q}' \langle \mathbf{q}| \frac{1}{QH^{\Lambda_0}Q} |\mathbf{q}'\rangle V^{\Lambda_0}(\mathbf{q}',0)$$

$$\beta(\mathbf{q};\Lambda) = -\int_\Lambda^{\Lambda_0} d\mathbf{q}' \langle \mathbf{q}| \frac{1}{QH^{\Lambda_0}Q} |\mathbf{q}'\rangle \frac{\partial^2}{\partial p^2} V^{\Lambda_0}(\mathbf{q}',\mathbf{p})\Big|_{\mathbf{p}=0}$$

State-independent
Wilson Coefficients

Anderson et al., PRC **82** (2010)
SKB and Roscher, PRC **86** (2012)

Effective operators from OPE

$$\langle \psi_\alpha^{\Lambda_0} | \widehat{O}_{\Lambda_0} | \psi_\alpha^{\Lambda_0} \rangle = \int_0^\Lambda dp \int_0^\Lambda dp' \, \psi_\alpha^{\Lambda_0 *}(p) O(p,p') \psi_\alpha^{\Lambda_0}(p') + \int_0^\Lambda dp \int_\Lambda^{\Lambda_0} dq \, \psi_\alpha^{\Lambda_0 *}(p) O(p,q) \psi_\alpha^{\Lambda_0}(q)$$

$$+ \int_\Lambda^{\Lambda_0} dq \int_0^\Lambda dp \, \psi_\alpha^{\Lambda_0 *}(q) O(q,p) \psi_\alpha^{\Lambda_0}(p) + \int_\Lambda^{\Lambda_0} dq \int_\Lambda^{\Lambda_0} dq' \, \psi_\alpha^{\Lambda_0 *}(q) O(q,q') \psi_\alpha^{\Lambda_0}(q')$$

Now use:

$$\psi_\alpha^{\Lambda_0}(\mathbf{q}) \approx \gamma(\mathbf{q};\Lambda) \int_0^\Lambda d^3p \, Z_\Lambda \psi_\alpha^\Lambda(\mathbf{p}) + \cdots$$ OPE for w.f.'s

$$\psi_\alpha^{\Lambda_0}(\mathbf{p}) \approx Z_\Lambda \psi_\alpha^\Lambda(\mathbf{p})$$ IR structure unaltered

$$O(q,p) \approx O(q,0) + \cdots$$ Scale separation

Effective operators from OPE

$$\langle \psi_\alpha^{\Lambda_0} | \widehat{O}_{\Lambda_0} | \psi_\alpha^{\Lambda_0} \rangle \approx Z_\Lambda^2 \langle \psi_\alpha^{\Lambda} | \widehat{O}_{\Lambda_0} | \psi_\alpha^{\Lambda} \rangle + g^{(0)}(\Lambda) \, \langle \psi_\alpha^{\Lambda} | \delta^{(3)}(\mathbf{r}) | \psi_\alpha^{\Lambda} \rangle + \cdots$$

state-independent
high-q physics
depends on operator

state dependent
soft m.e. (low-k)
same for all high-q operators

E.g.,

$$\begin{aligned} g^{(0)}(\Lambda) \equiv{}& 2Z_\Lambda^2 \int_\Lambda^{\Lambda_0} d\tilde{q}\, O(0,q)\gamma(q;\Lambda) \\ &+ Z_\Lambda^2 \int_\Lambda^{\Lambda_0} d\tilde{q} \int_\Lambda^{\Lambda_0} d\tilde{q}'\, \gamma^*(q;\Lambda) O(q,q')\gamma(q';\Lambda) \end{aligned}$$

Generically:

$$\widehat{O}_\Lambda = Z_\Lambda^2 \, \widehat{O}_{\Lambda_0} + g^{(0)}(\Lambda)\, \delta(\mathbf{r}) + g^{(2)}(\Lambda)\, \nabla^2 \delta(\mathbf{r}) + \cdots$$

Scaling of high momentum tails

How does an operator that probes high-momentum w.f. components look in a low-momentum effective theory?

$$\langle\psi_\alpha^{\Lambda_0}|\widehat{O}_{\Lambda_0}|\psi_\alpha^{\Lambda_0}\rangle \approx Z_\Lambda^2\langle\psi_\alpha^{\Lambda}|\widehat{O}_{\Lambda_0}|\psi_\alpha^{\Lambda}\rangle + g^{(0)}(\Lambda)\,\langle\psi_\alpha^{\Lambda}|\delta^{(3)}(\mathbf{r})|\psi_\alpha^{\Lambda}\rangle + \cdots$$

= 0 since $P_\Lambda O_{\Lambda_0} P_\Lambda = 0$

E.g., momentum distribution for q >> Λ

$$\langle\psi_\alpha^{\Lambda_0}|a_{\mathbf{q}}^\dagger a_{\mathbf{q}}|\psi_\alpha^{\Lambda_0}\rangle \approx \gamma^2(\mathbf{q};\Lambda)\; Z_\Lambda^2|\langle\psi_\alpha^{\Lambda}|\delta(\mathbf{r})|\psi_\alpha^{\Lambda}\rangle|^2$$

low-E states have the same large-q tails if leading OPE term dominates

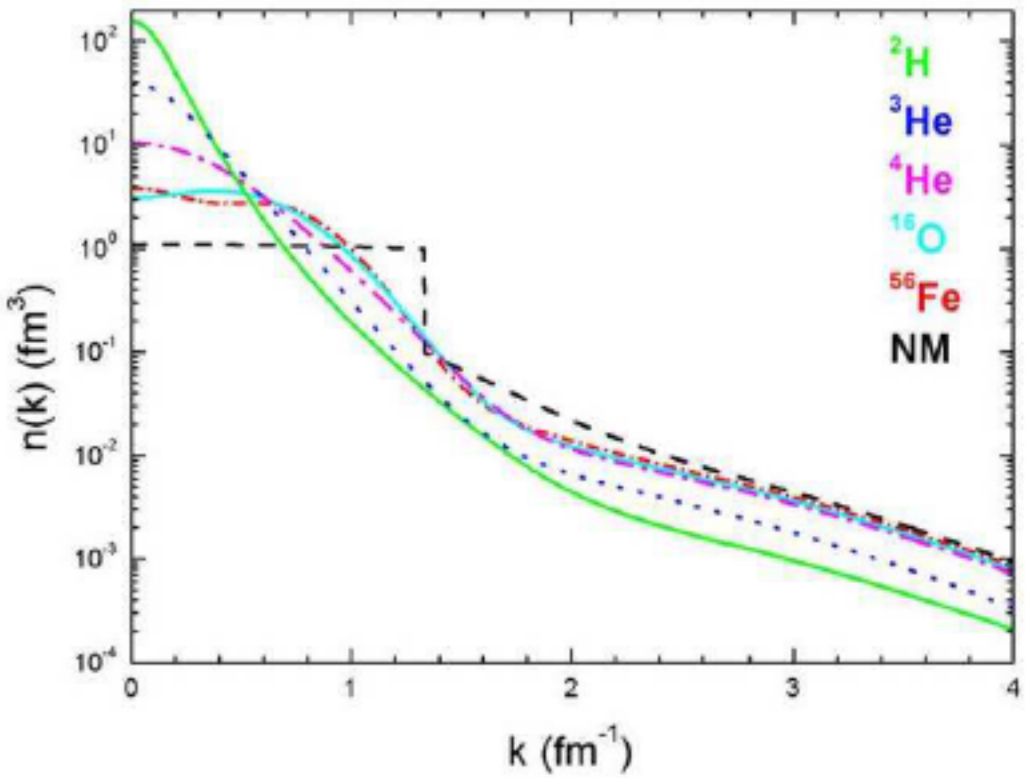
Generalize to arbitrary **A-body** states?

Scaling of high momentum tails

SKB and Roscher, PRC **86** (2012)

Ex1: momentum distribution from **leading order** OPE (Λ << q < Λ_0):

$$\langle\psi^{\Lambda_0}_{\alpha,A}|a^\dagger_{\mathbf{q}}a_{\mathbf{q}}|\psi^{\Lambda_0}_{\alpha,A}\rangle \approx \gamma^2(\mathbf{q};\Lambda) \times \sum_{\mathbf{k},\mathbf{k}',\mathbf{K}}^{\Lambda} Z^2_\Lambda\,\langle\psi^{\Lambda}_{\alpha,A}|a^\dagger_{\frac{\mathbf{K}}{2}+\mathbf{k}}a^\dagger_{\frac{\mathbf{K}}{2}-\mathbf{k}}a_{\frac{\mathbf{K}}{2}-\mathbf{k}'}a_{\frac{\mathbf{K}}{2}+\mathbf{k}'}|\psi^{\Lambda}_{\alpha,A}\rangle$$



[From C. Ciofi degli Atti and S. Simula]

$$C(A,2) \equiv \frac{n_A(\mathbf{q})}{n_D(\mathbf{q})} \sim \frac{\sum_{\mathbf{k},\mathbf{k}',\mathbf{K}}\langle\psi^{\Lambda}_{\alpha,A}|a^\dagger_{\frac{\mathbf{K}}{2}+\mathbf{k}}a^\dagger_{\frac{\mathbf{K}}{2}-\mathbf{k}}a_{\frac{\mathbf{K}}{2}-\mathbf{k}'}a_{\frac{\mathbf{K}}{2}+\mathbf{k}'}|\psi^{\Lambda}_{\alpha,A}\rangle}{\sum_{\mathbf{k},\mathbf{k}',\mathbf{K}}\langle\psi^{\Lambda}_{\alpha,D}|a^\dagger_{\frac{\mathbf{K}}{2}+\mathbf{k}}a^\dagger_{\frac{\mathbf{K}}{2}-\mathbf{k}}a_{\frac{\mathbf{K}}{2}-\mathbf{k}'}a_{\frac{\mathbf{K}}{2}+\mathbf{k}'}|\psi^{\Lambda}_{\alpha,D}\rangle}$$

Scaling of high momentum tails

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SKB and Roscher, PRC **86** (2012)

Ex2: static structure factor from **leading order** OPE (Λ << q < Λ_0):

$$\langle \psi^{\Lambda_0}_{\alpha,A} | \widehat{S}(\mathbf{q}) | \psi^{\Lambda_0}_{\alpha,A} \rangle \approx \Big\{ 2\gamma(\mathbf{q};\Lambda) + \sum_{\mathbf{P}} \gamma(\mathbf{P}+\mathbf{q};\Lambda)\gamma(\mathbf{P};\Lambda) \Big\}$$

$$\times \sum_{\mathbf{K},\mathbf{k},\mathbf{k}'}^{\Lambda} Z^2_\Lambda \, \langle \psi^{\Lambda}_{\alpha,A} | a^\dagger_{\frac{\mathbf{K}}{2}+\mathbf{k}} a^\dagger_{\frac{\mathbf{K}}{2}-\mathbf{k}} a_{\frac{\mathbf{K}}{2}-\mathbf{k}'} a_{\frac{\mathbf{K}}{2}+\mathbf{k}'} | \psi^{\Lambda}_{\alpha,A} \rangle$$

- hard (high q) physics
- Universal (state-indep)
- fixed from A=2

X

- soft (low-k) m.e.
- same for all high-q probes
- A-dependent scale factor

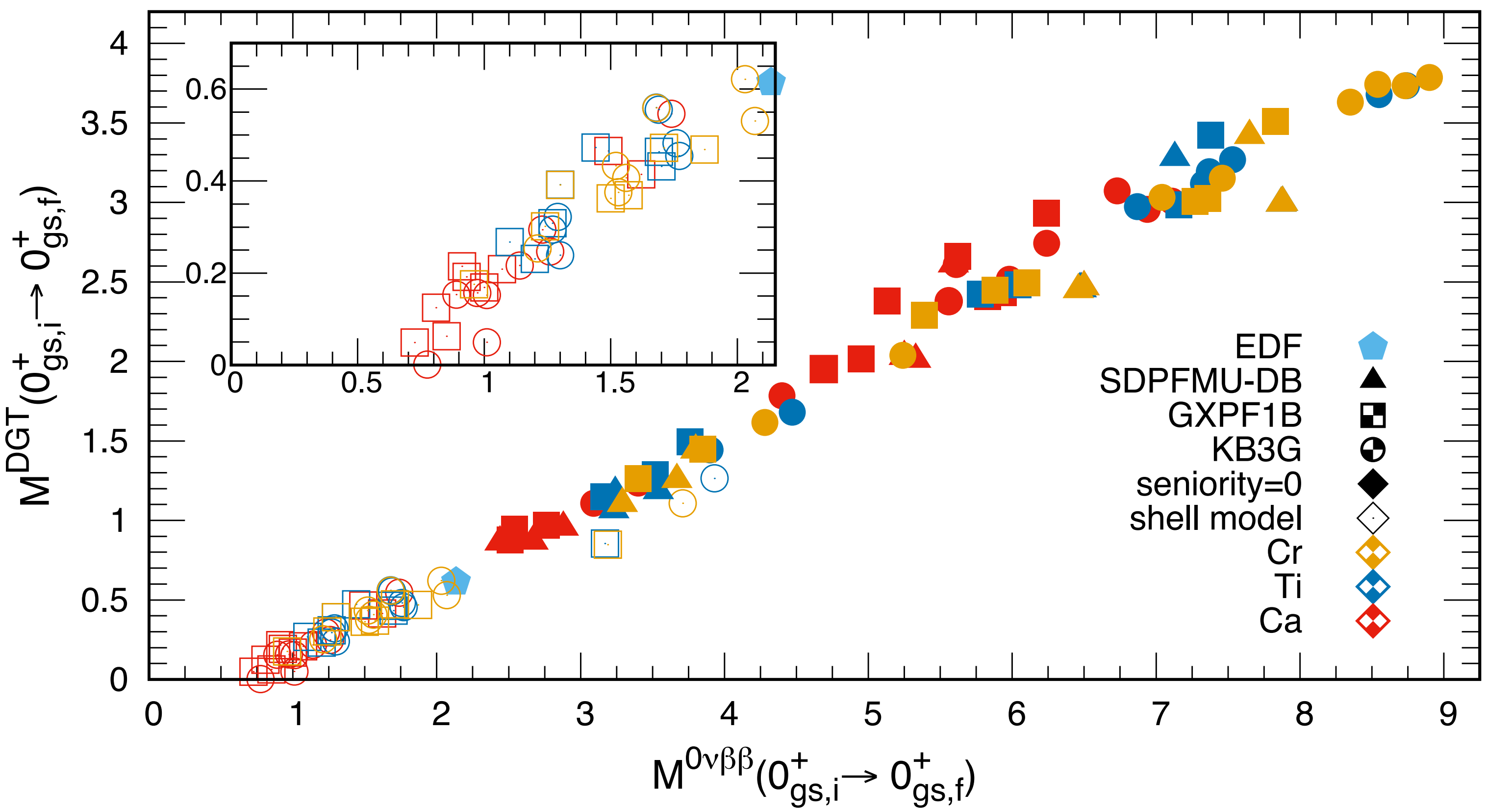
OPE links few- and A-body systems (cf talks of R. Weiss and J. Ryckebusch)

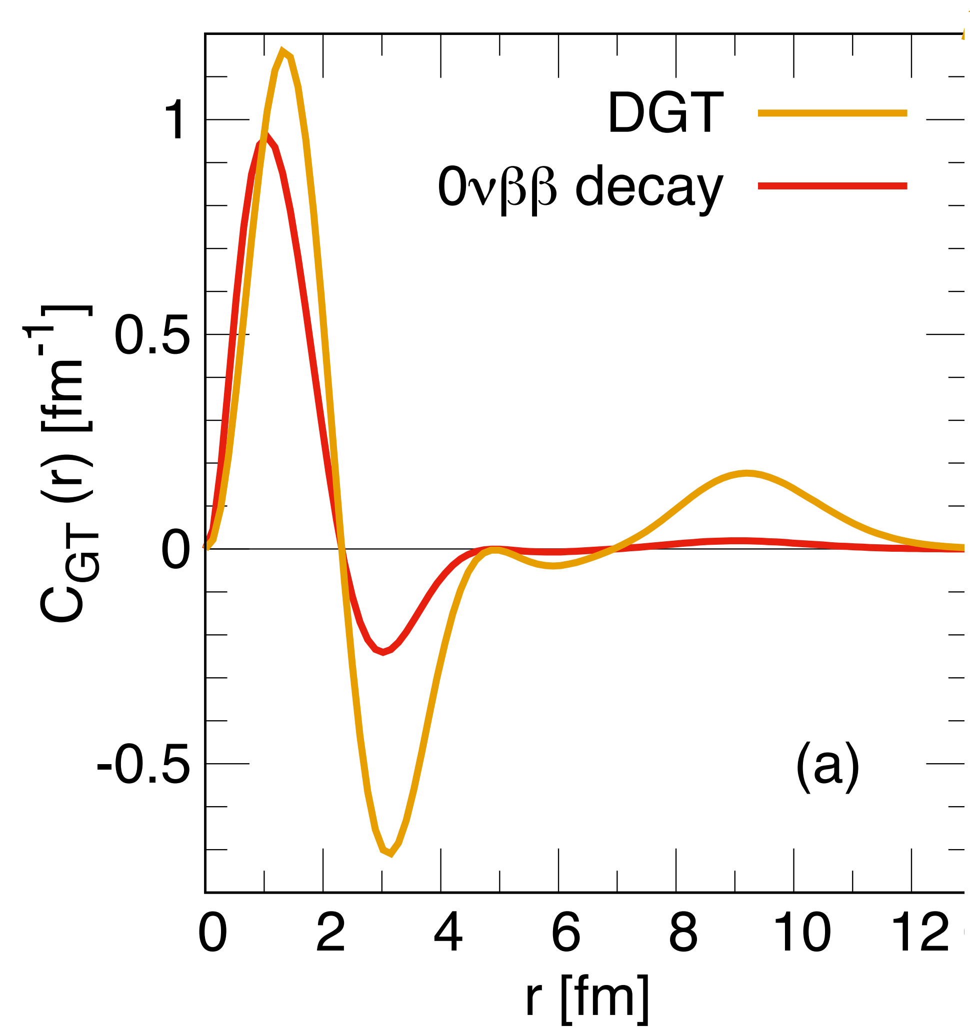
Correlations/scaling for 2 observables w/same leading OPE (e.g., EMC-SRC)

Subleading OPE ==> deviations from scaling calculable in principle

Ex: 0νββ and Double GT correlation

Shimizu, Menendez, Yako PRL 120 (2018)





DGT and 0νββ operators main contribution for r < 2 fm

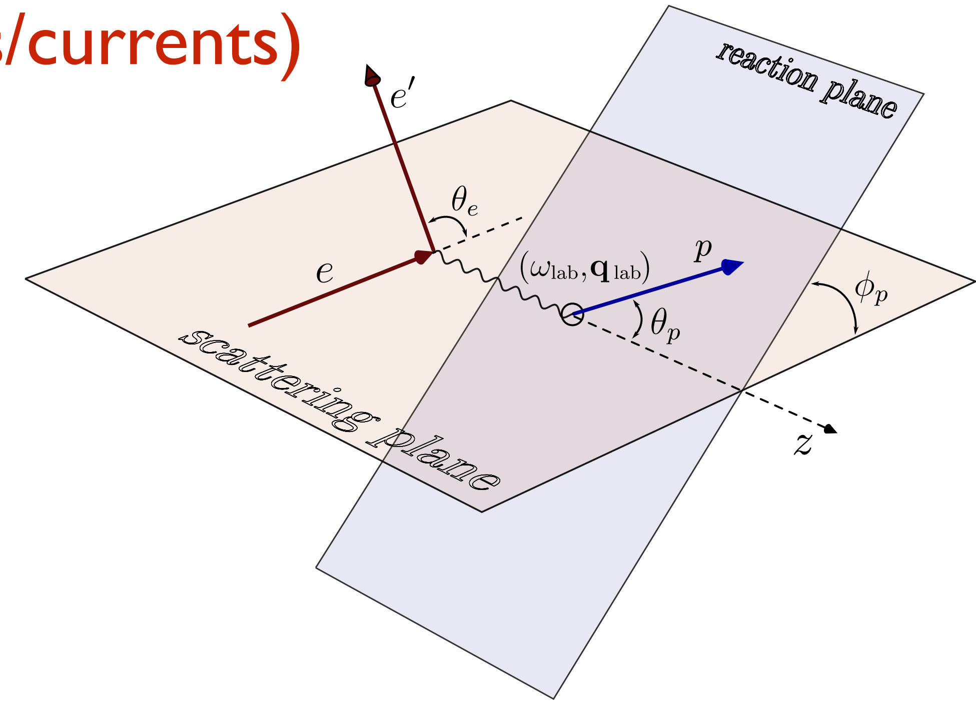
Same leading operator in OPE => linear relation

slope at ~10-15% level

Scale dependence of deuteron electrodisintegration

Test ground: ^{2}H(e,e′p)n

- Simplest knockout process (no induced 3N forces/currents)
- Focus on longitudinal structure function f_L

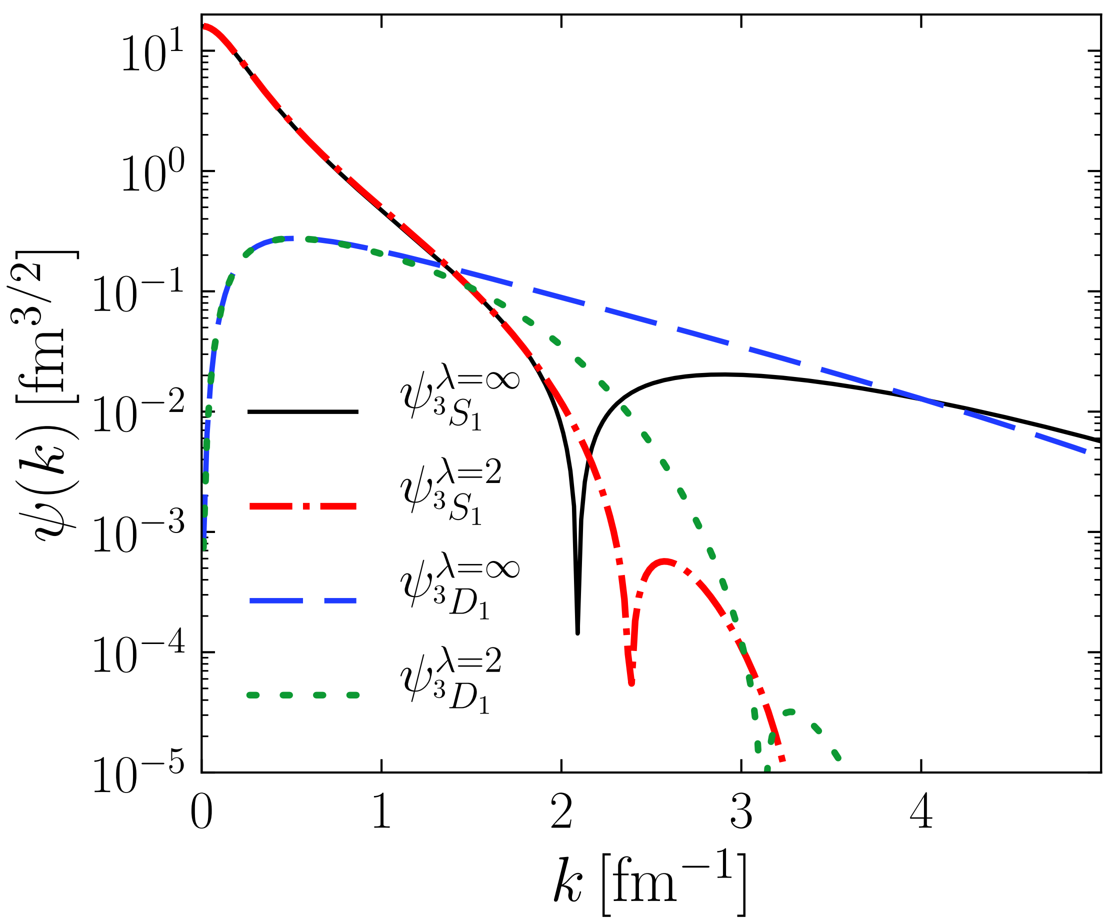


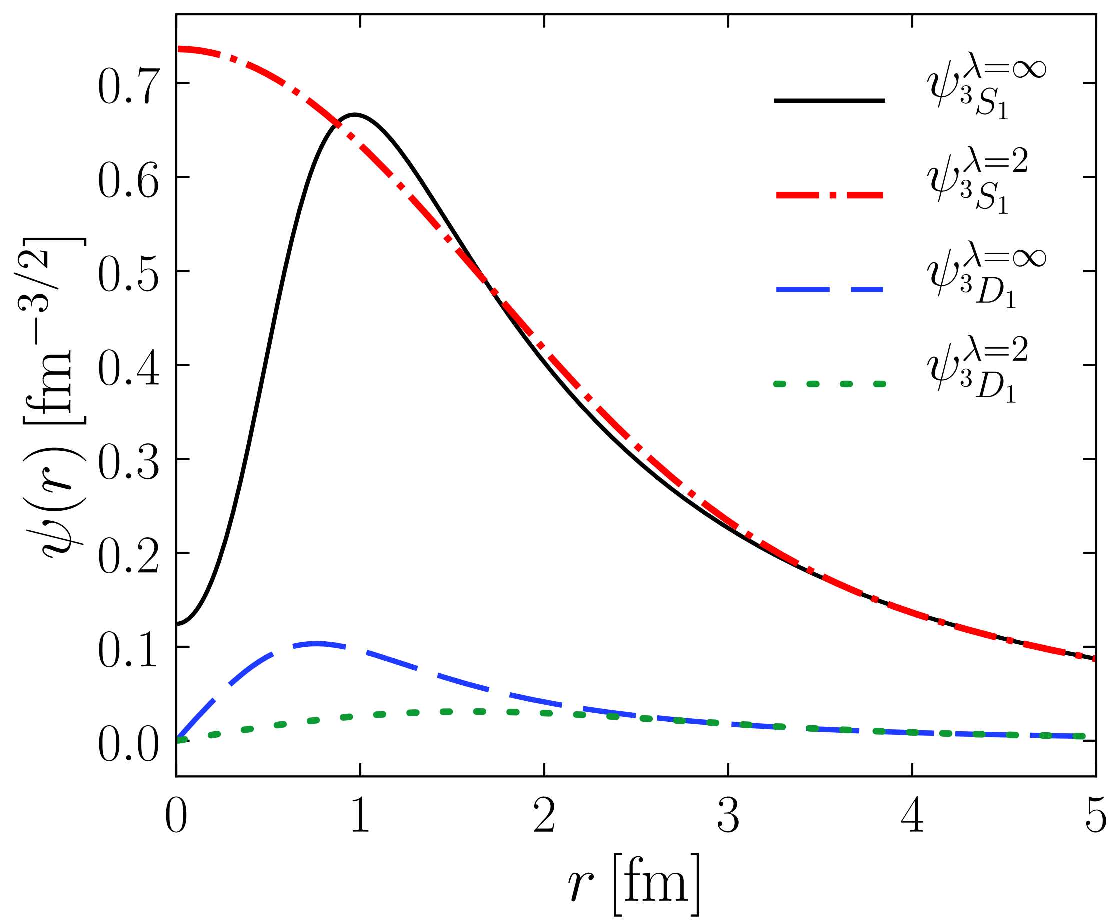
$$f_L \sim \sum_{m_s, m_J} \left| \langle \psi_f | J_0 | \psi_i \rangle \right|^2$$

- $$f_L^\lambda \sim \left| \langle \underbrace{\psi_f | U_\lambda^\dagger}_{\psi_f^\lambda} \, \underbrace{U_\lambda \, J_0 \, U_\lambda^\dagger}_{J_0^\lambda} \, \underbrace{U_\lambda \, | \psi_i}_{\psi_i^\lambda} \rangle \right|^2; \quad U_\lambda^\dagger U_\lambda = I; \quad f_L^\lambda = f_L$$

- Components (deuteron wf, transition operator, FSI) scale-dependent, total is not.
- Are some resolutions "better" than others? E.g., in a given kinematics, can FSI be minimized with different choices of λ?? How do interpretations change with scale?

Deuteron wave function evolution



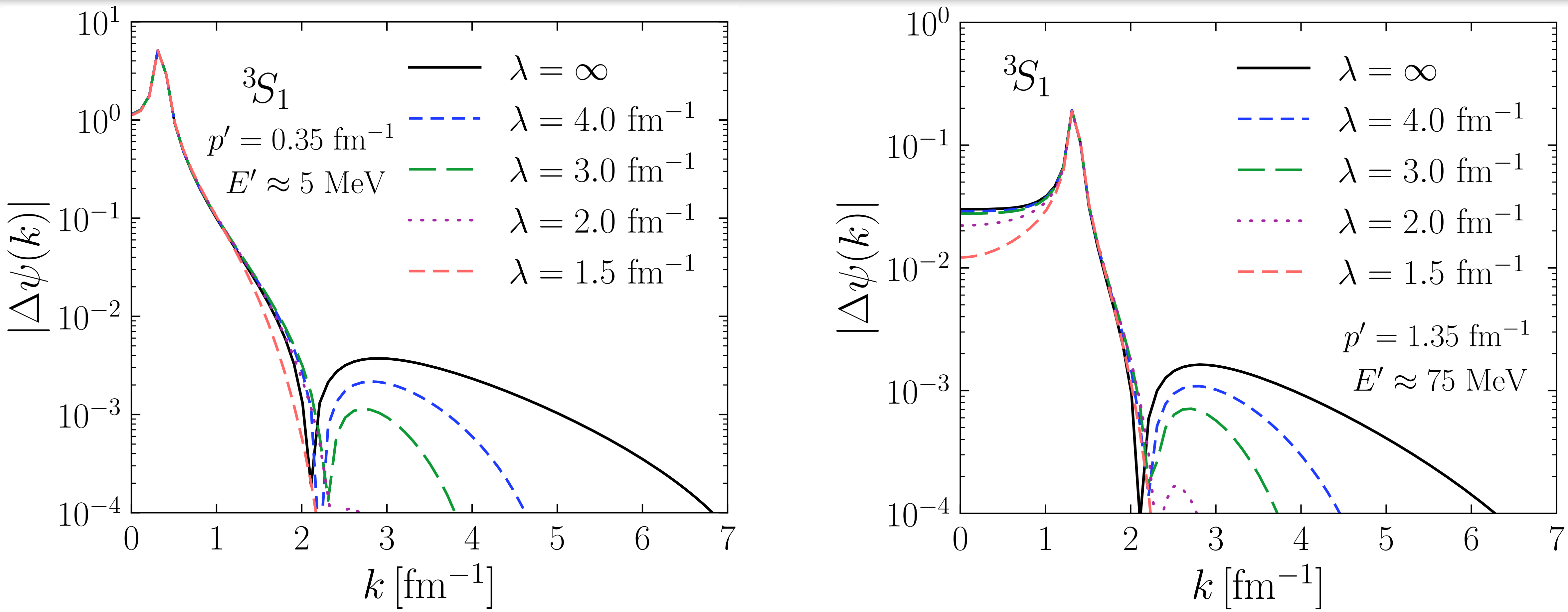


k < λ components invariant <==> RG preserves long-distance physics

k > λ components suppressed <==> short-range correlations blurred out

Folklore: Simple wave functions at low λ <==> more complicated operators?
especially for high-q processes?

Final-state wave function evolution



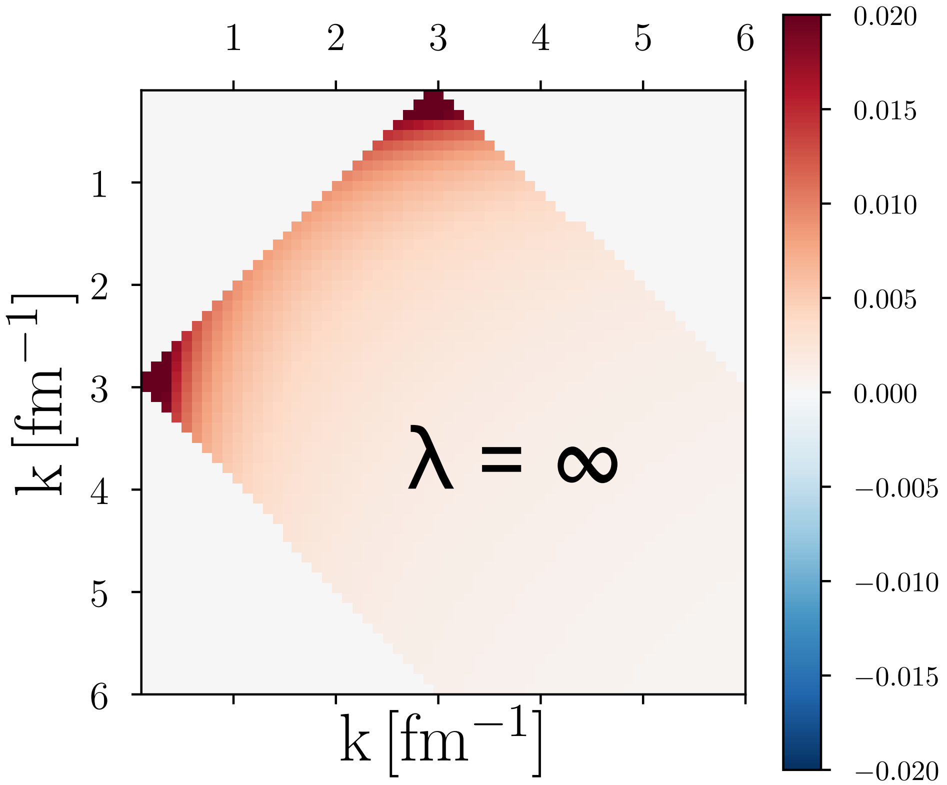
$$\psi_f^\lambda(p';k) = \underbrace{\phi_{p'}}_{\text{IA}} + \underbrace{\Delta\psi_\lambda(p';k)}_{\text{FSI}}$$

- High-k tail suppressed with evolution
- For $p' \gtrsim \lambda$, $\Delta\psi_f^\lambda(p';k)$ localized around outgoing p′

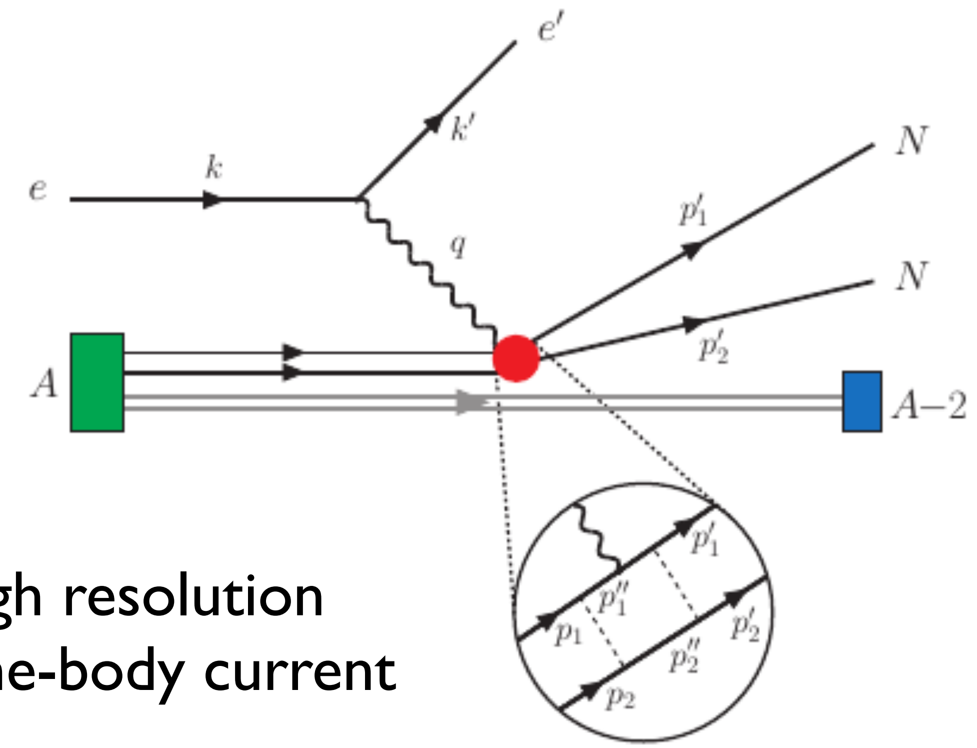
"local decoupling" Dainton et al. PRC 89 (2014)

Current operator evolution

$^3S_1$ channel



$q^2 = 36\ \mathrm{fm}^{-2}$

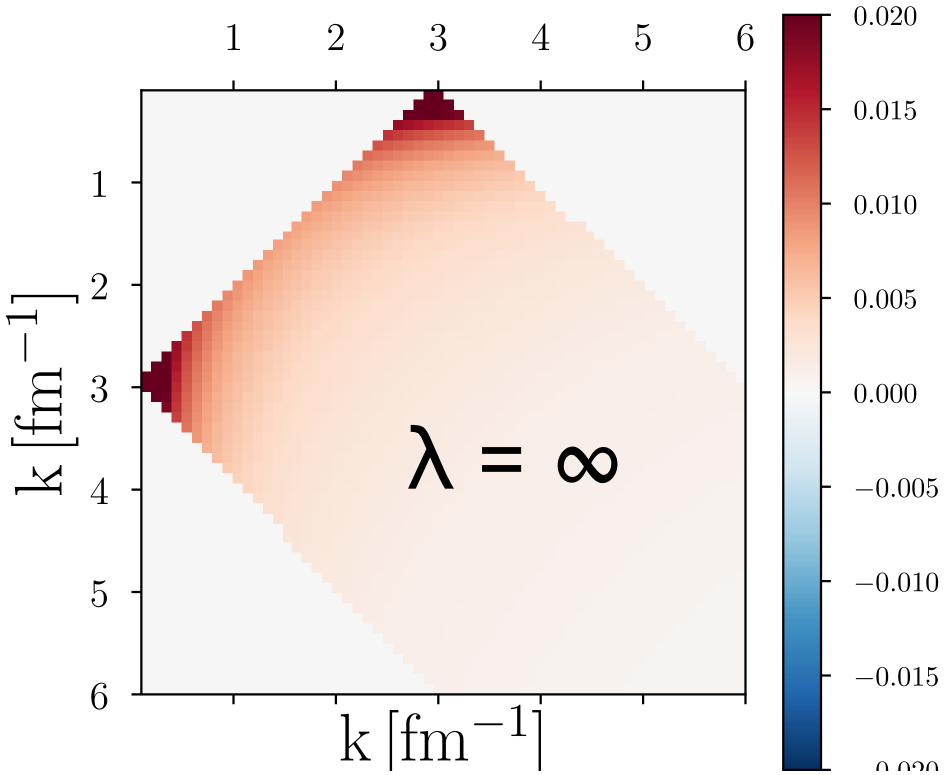


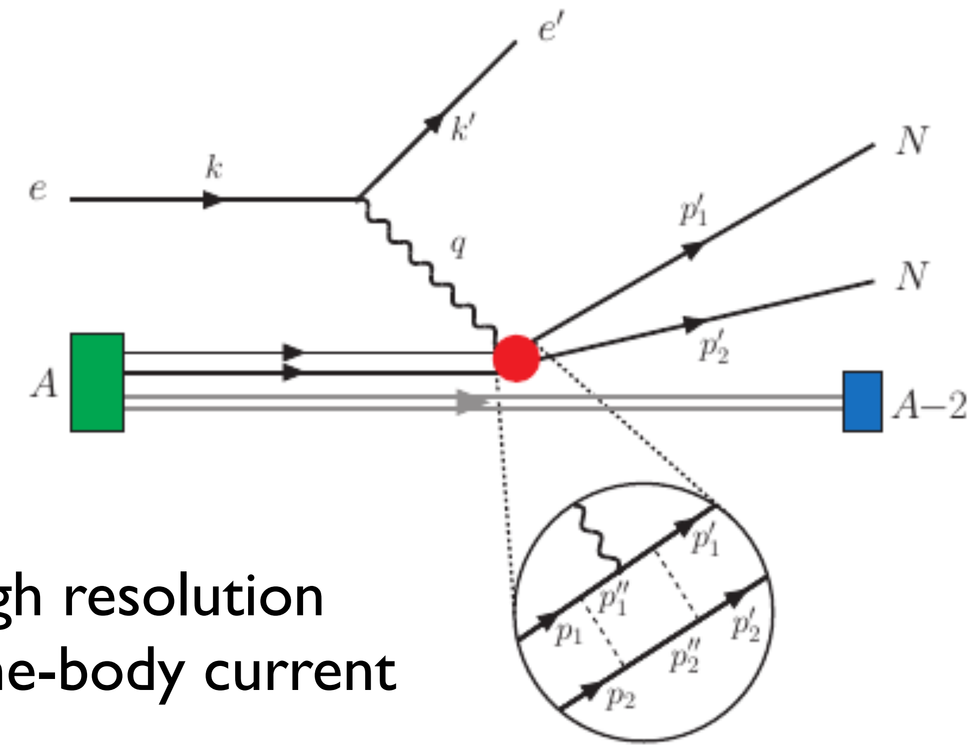
high resolution
one-body current

Current operator evolution

$^3S_1$ channel

$q^2 = 36\ \mathrm{fm}^{-2}$





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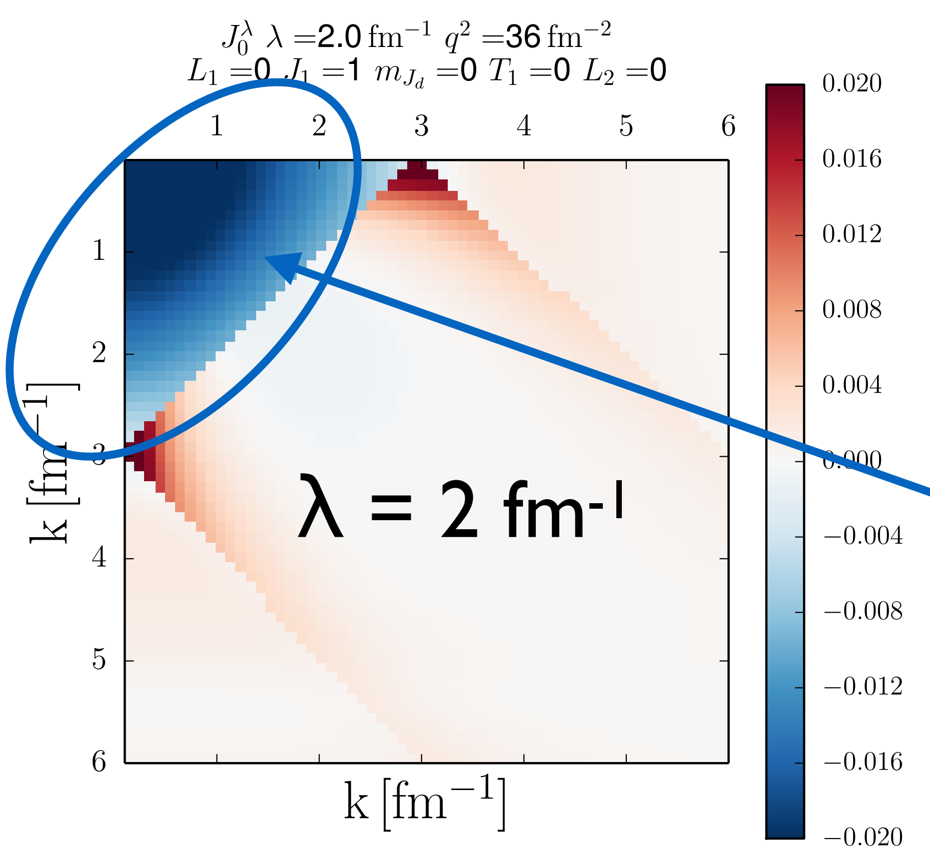

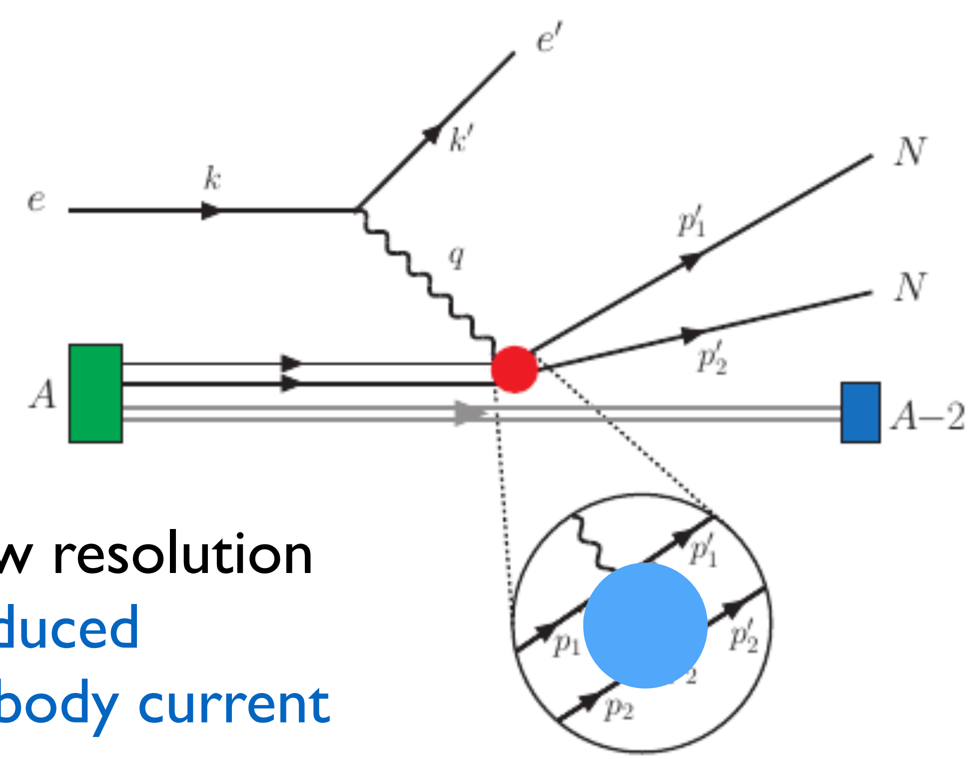

low resolution
induced
2-body current

λ dependence of Final State Interactions

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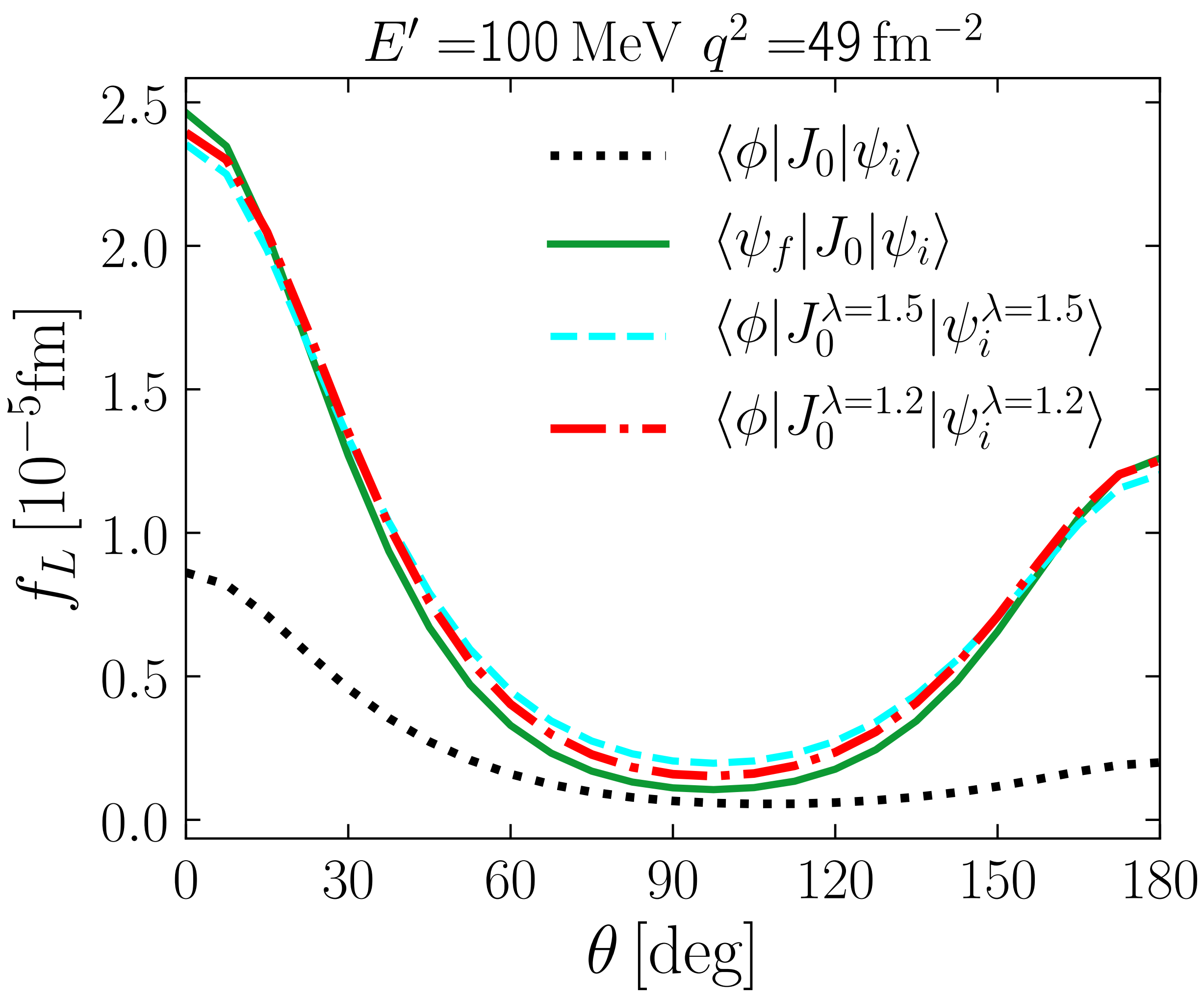
Look at kinematics relevant to SRC studies



x_B=1.64, Q^2= 1.78 GeV^2

FSI sizable at large λ
but negligible at low-resolution!

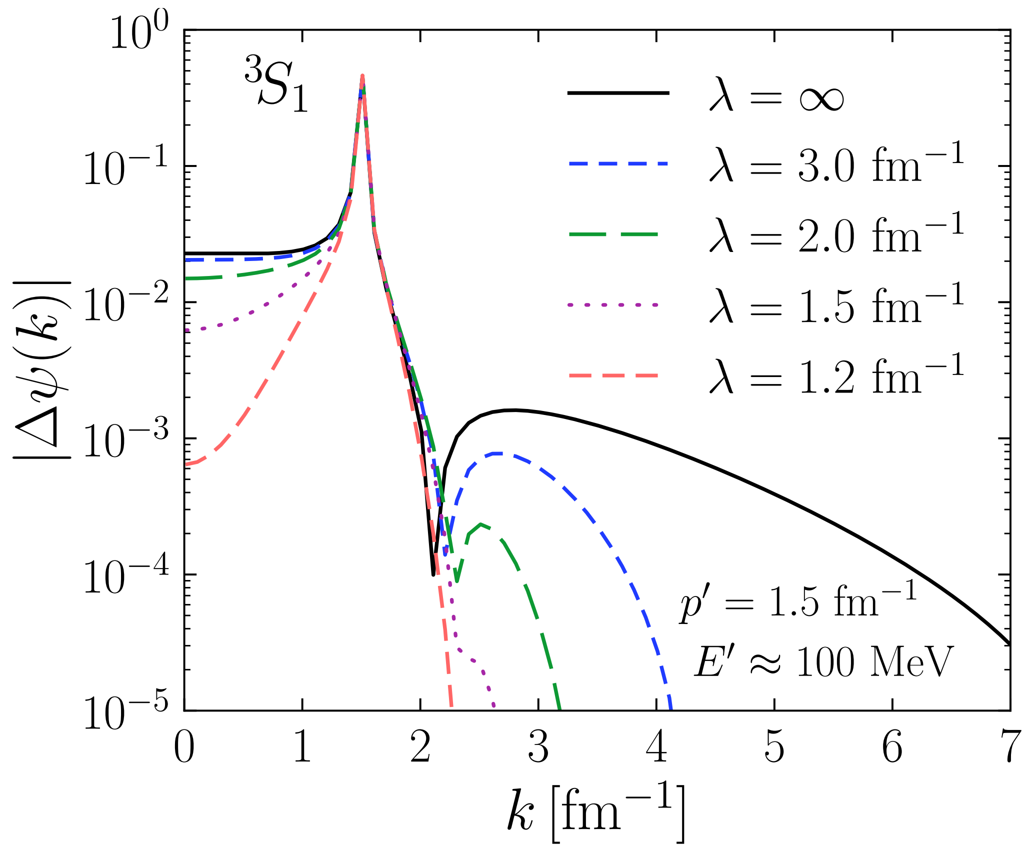
Folklore:

shouldn't hard processes
be complicated in low resolution
(λ << q) pictures?

Why are FSI so small at low λ ?

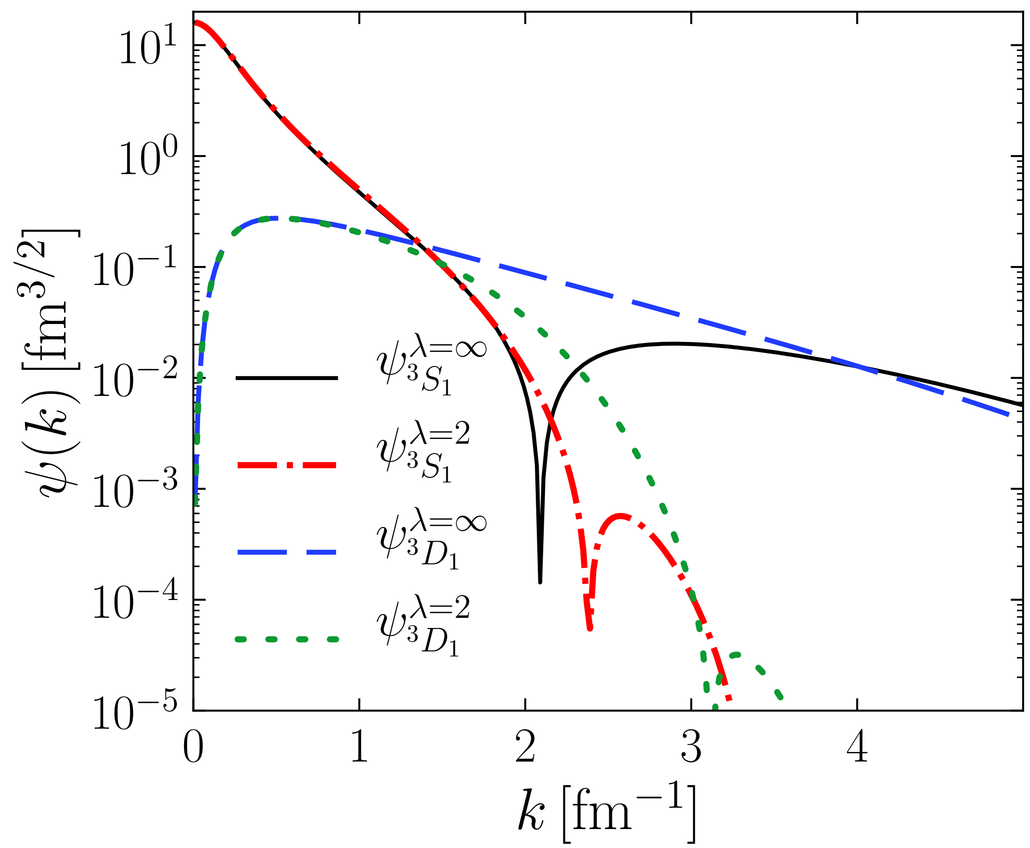
λ dependence of Final State Interactions

final state wf (interacting piece)



For p′ ≳ λ, interacting part of final state wf localized at k ≈ p′

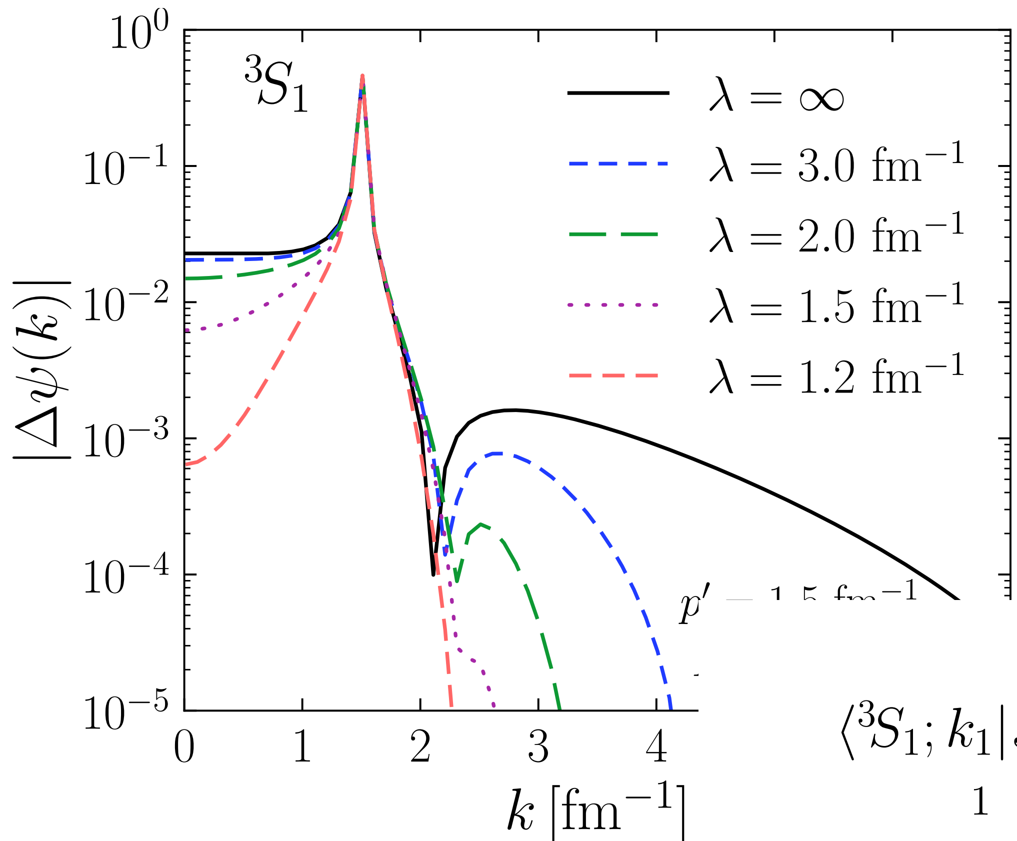
initial state (deuteron) wf



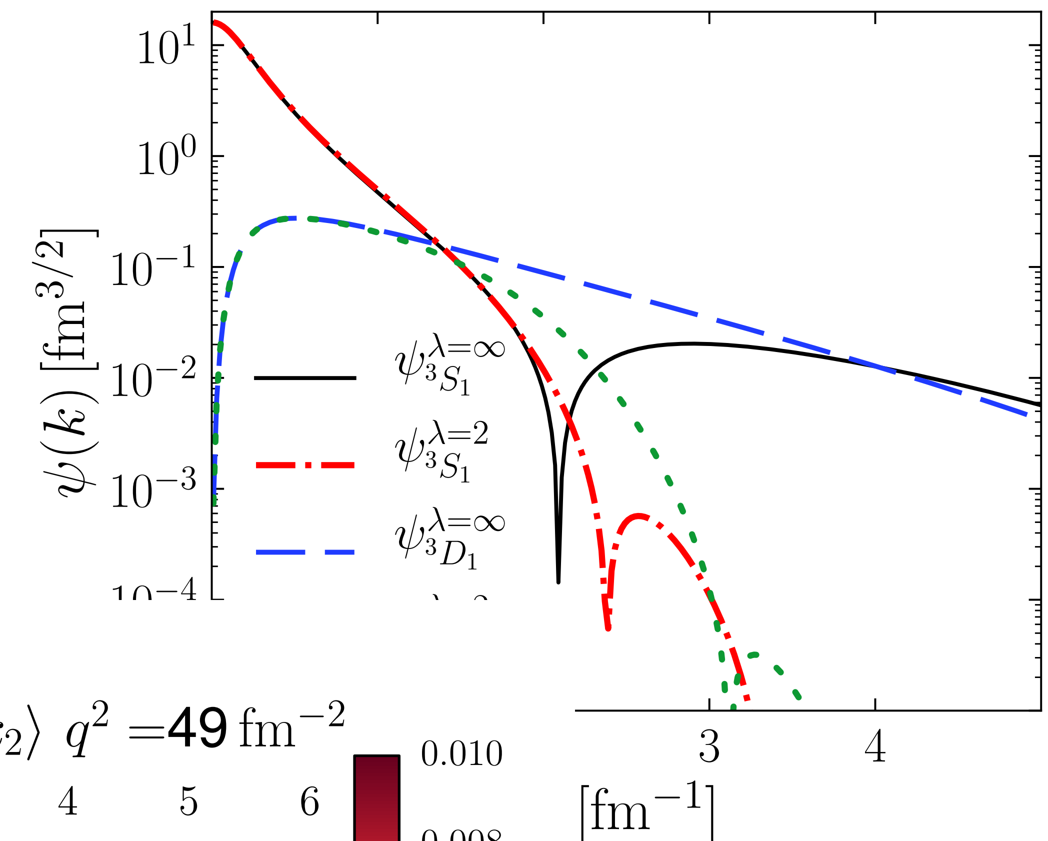
Dominant support of deuteron wf at k ≲ λ

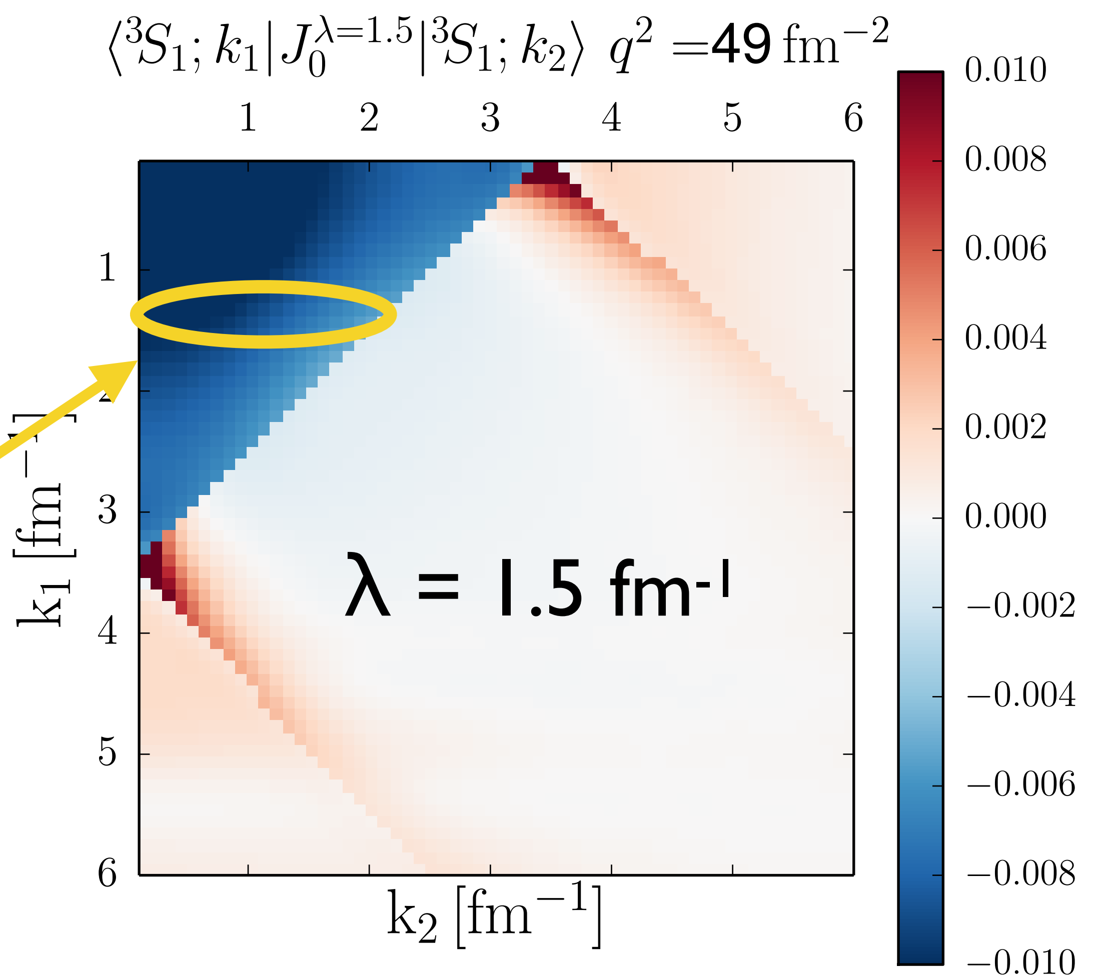
λ dependence of Final State Interactions

final state wf (interacting piece)



initial state (deuteron) wf





$J^\lambda_{\mathbf{q}}(k', k)$
probed by transition

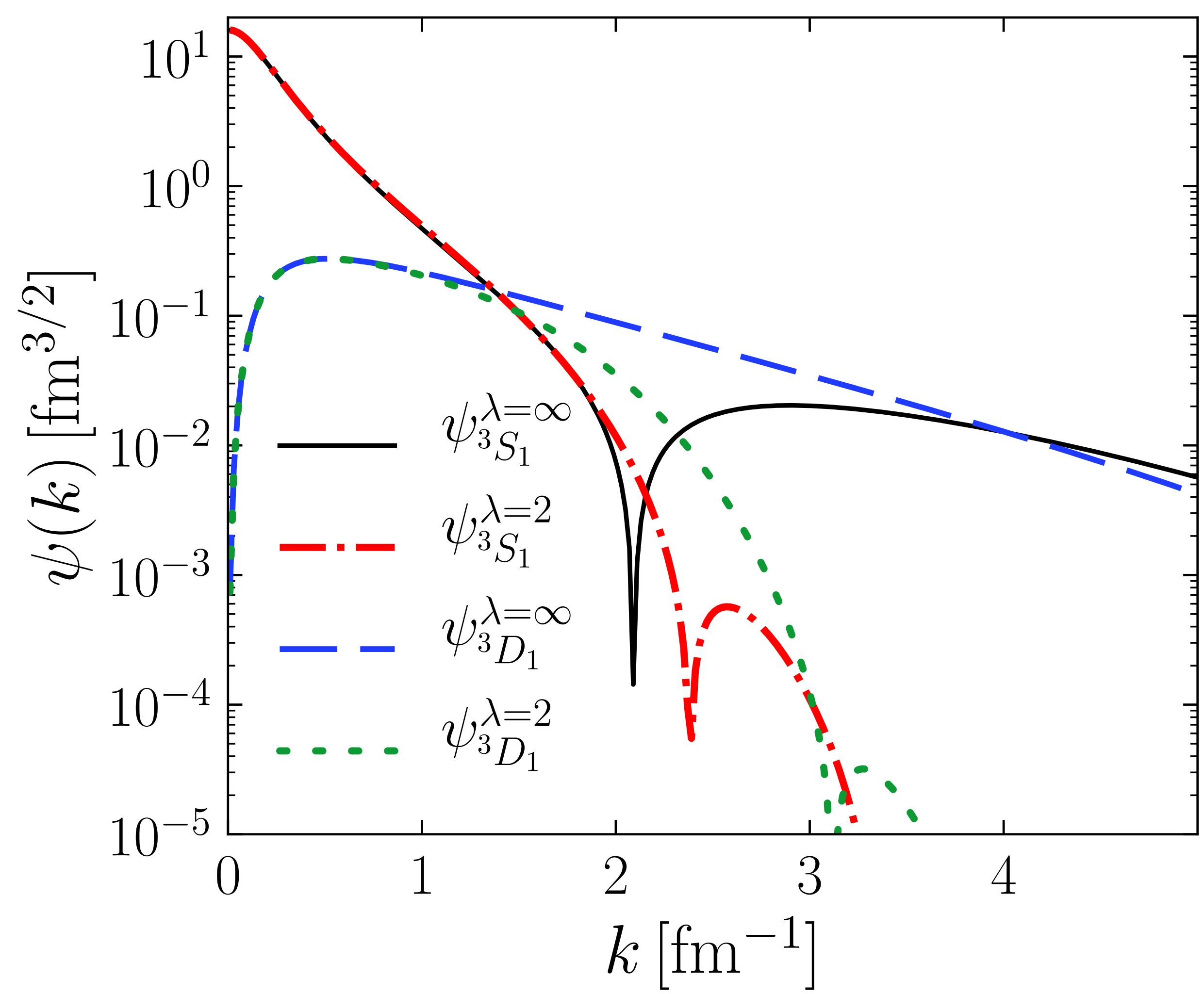
(smooth and non-singular)

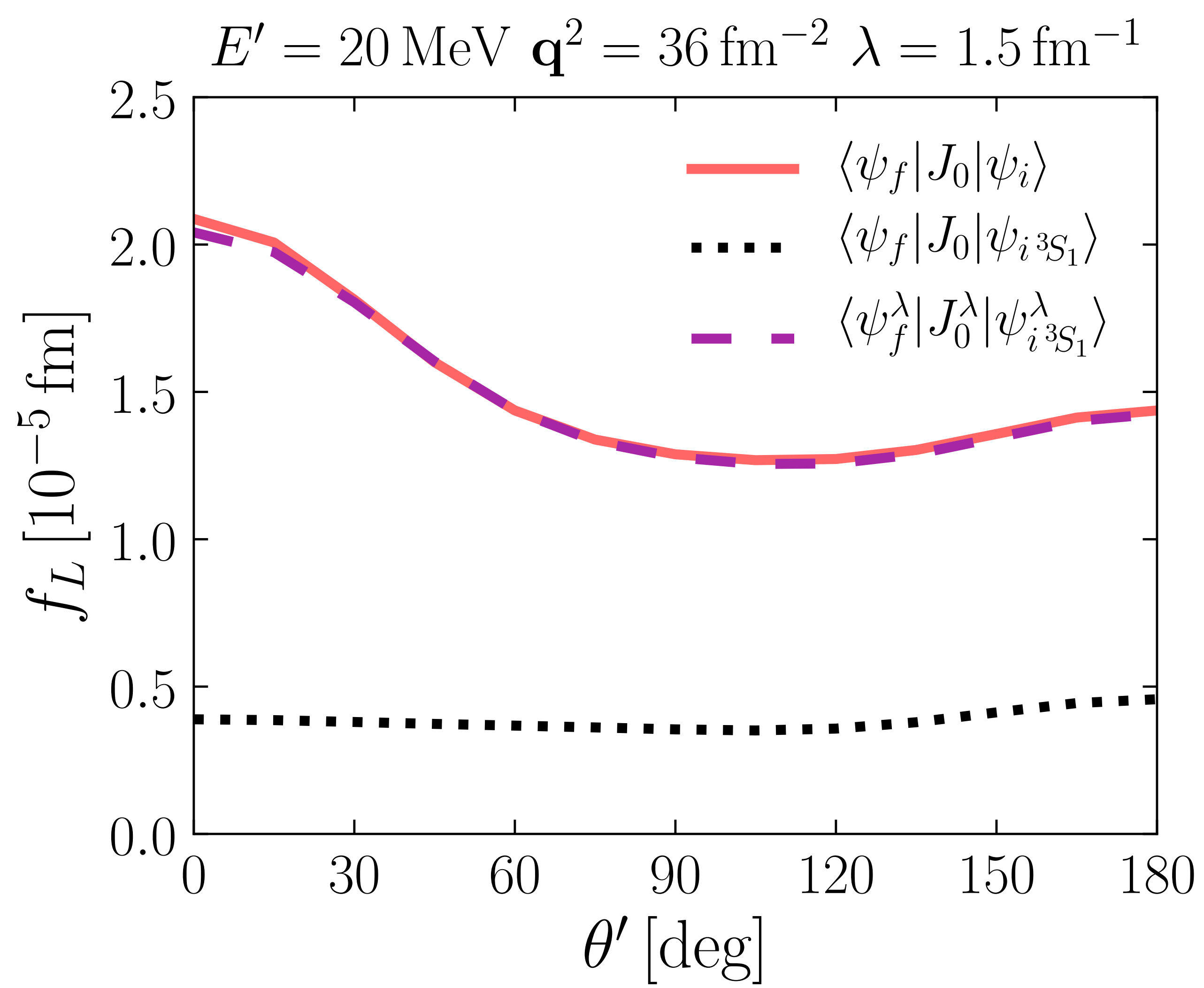
∴ FSI ~ T(p',p')

(small!)

λ dependence of interpretations

- Analysis/interpretation of a reaction involves understanding which part of wave functions probed (highly scale dependent!)
- E.g., sensitivity to D-state w.f. in large $\mathbf{q}^2$ processes





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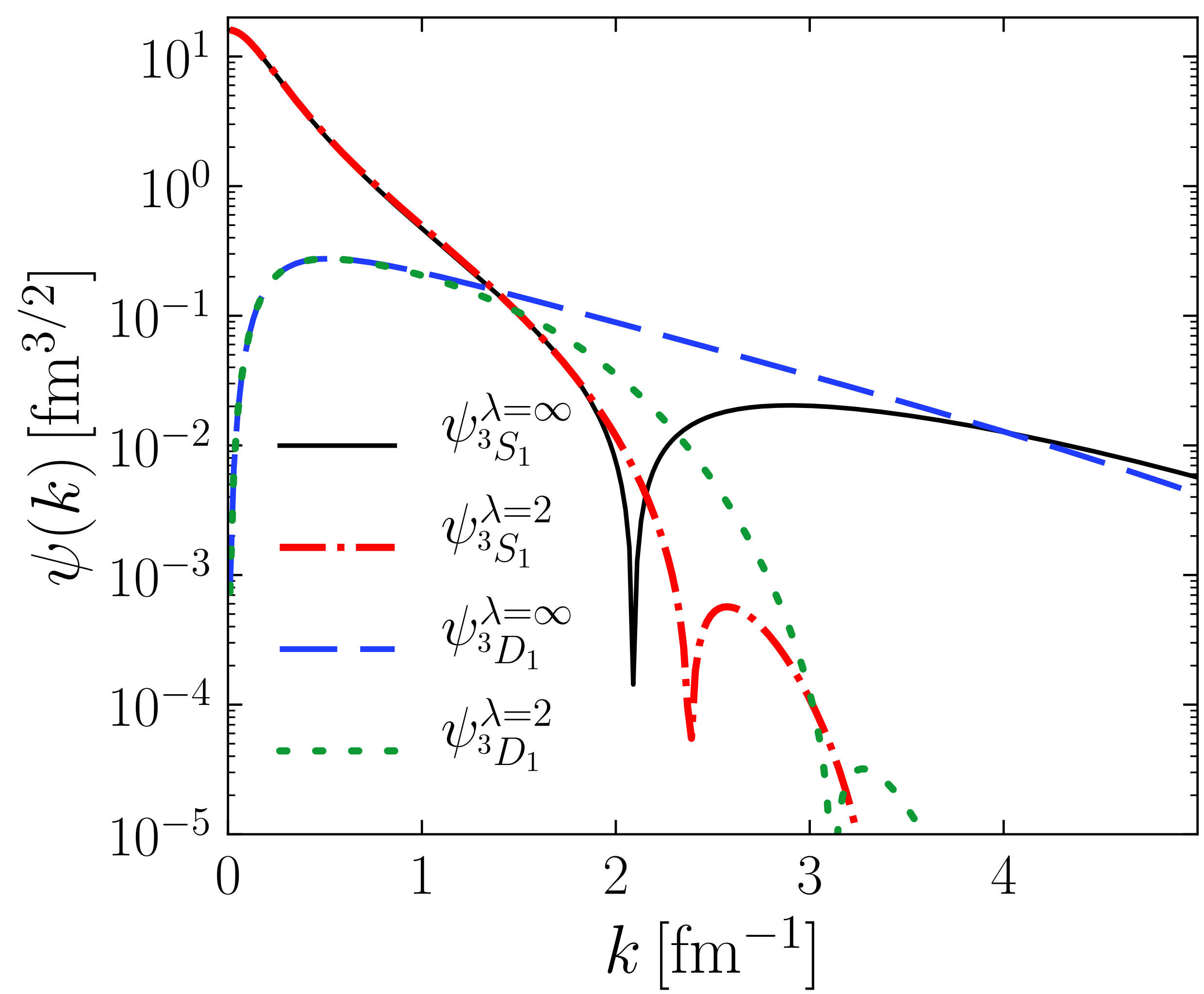
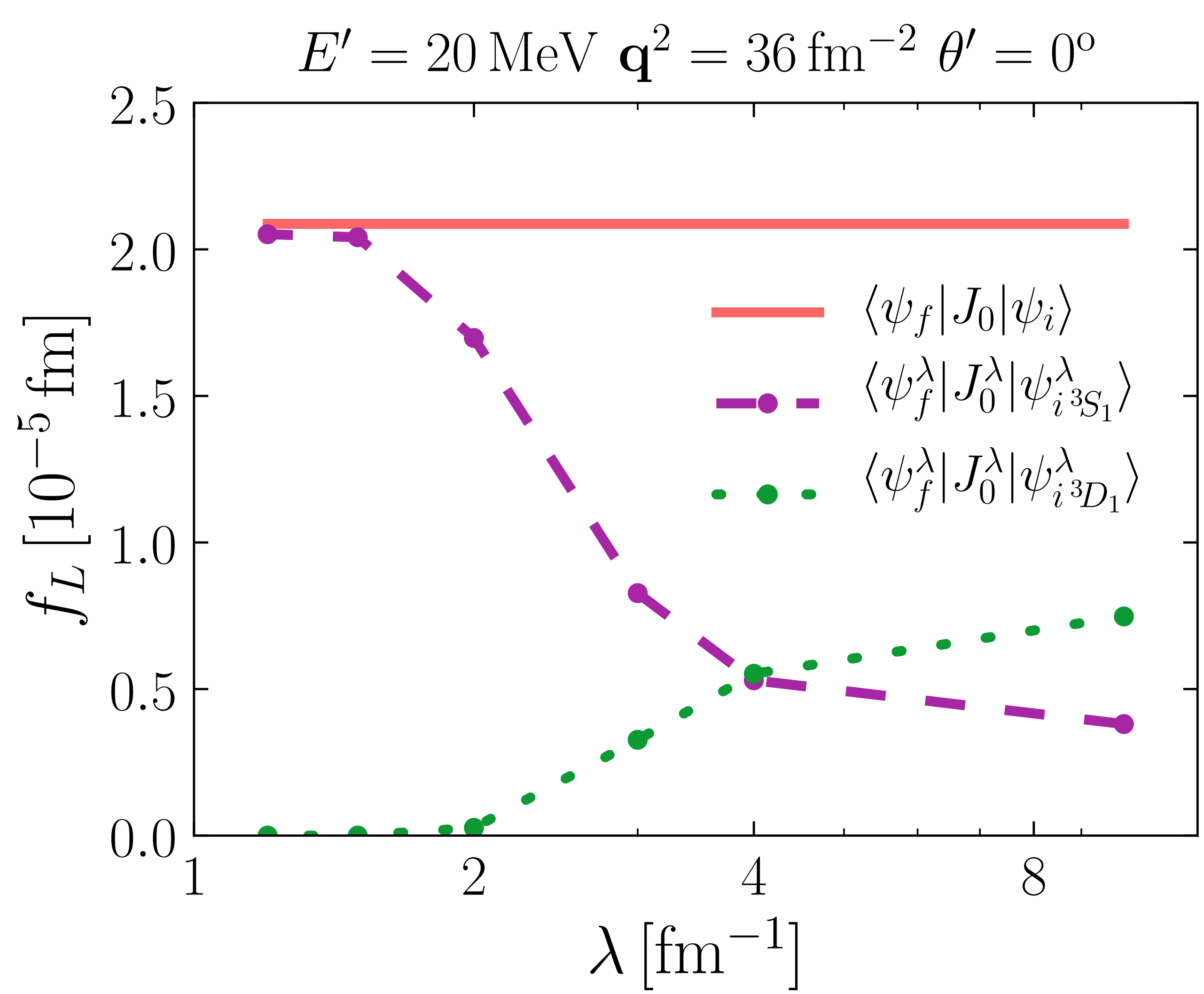
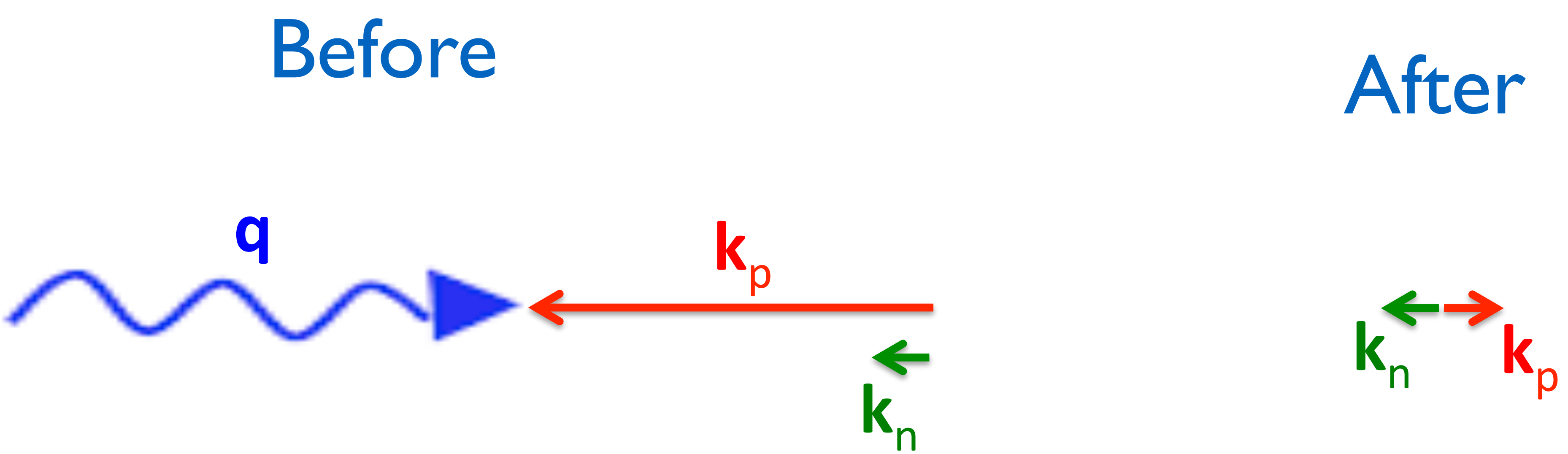




λ dependence of SRC interpretation

- Consider large q^2 near threshold (small p') for $\theta=0$ in **high-resolution** picture (COM frame of outgoing np)



photon only couples to proton

λ dependence of SRC interpretation

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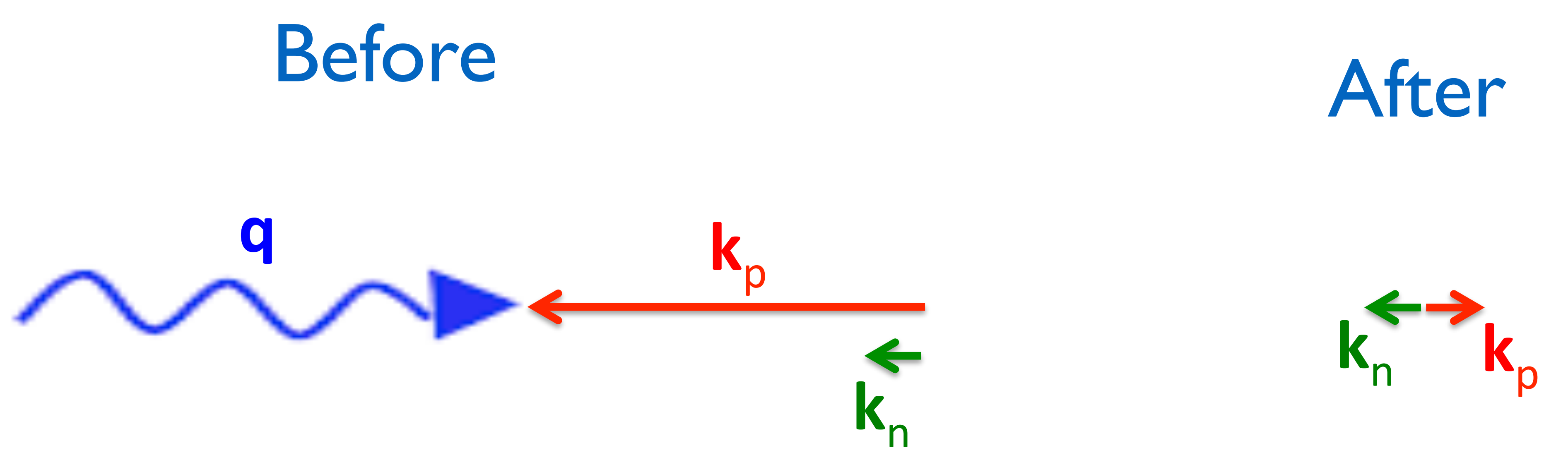


photon only couples to proton

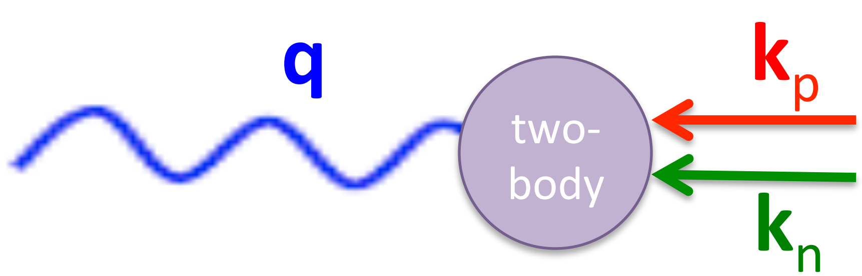
∴ proton has large momentum => initial large relative momentum

(i.e., SRC pair)

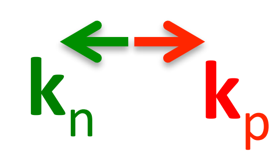
λ dependence of SRC interpretation

- Consider large q^2 near threshold (small p') for $\theta=0$ in **low-resolution** picture (COM frame of outgoing np)

Before

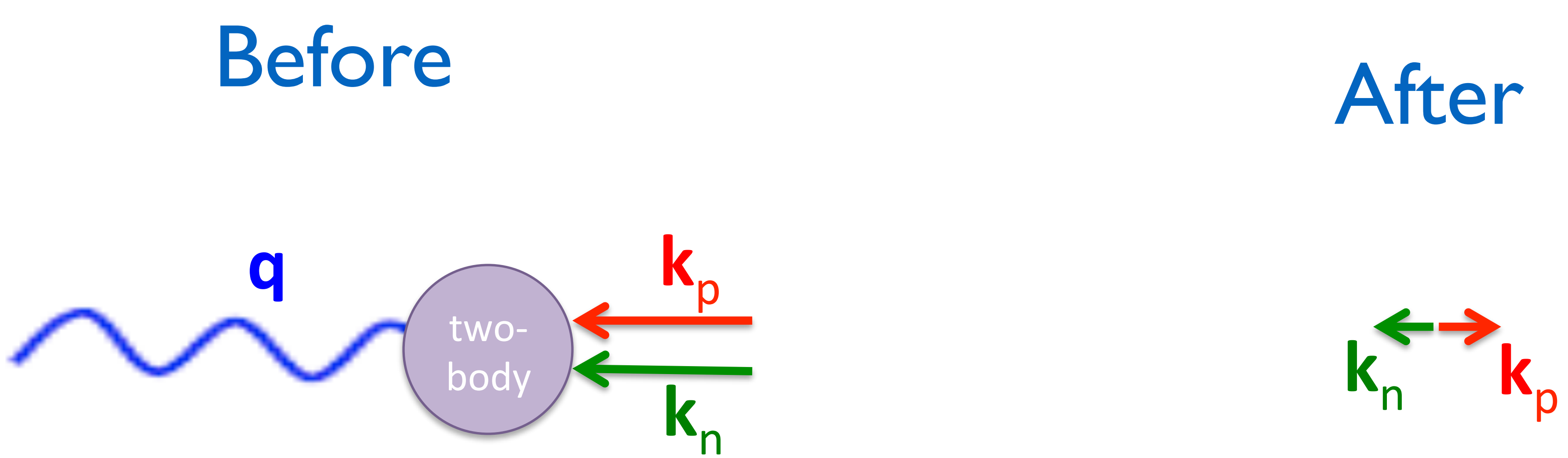


After



λ dependence of SRC interpretation

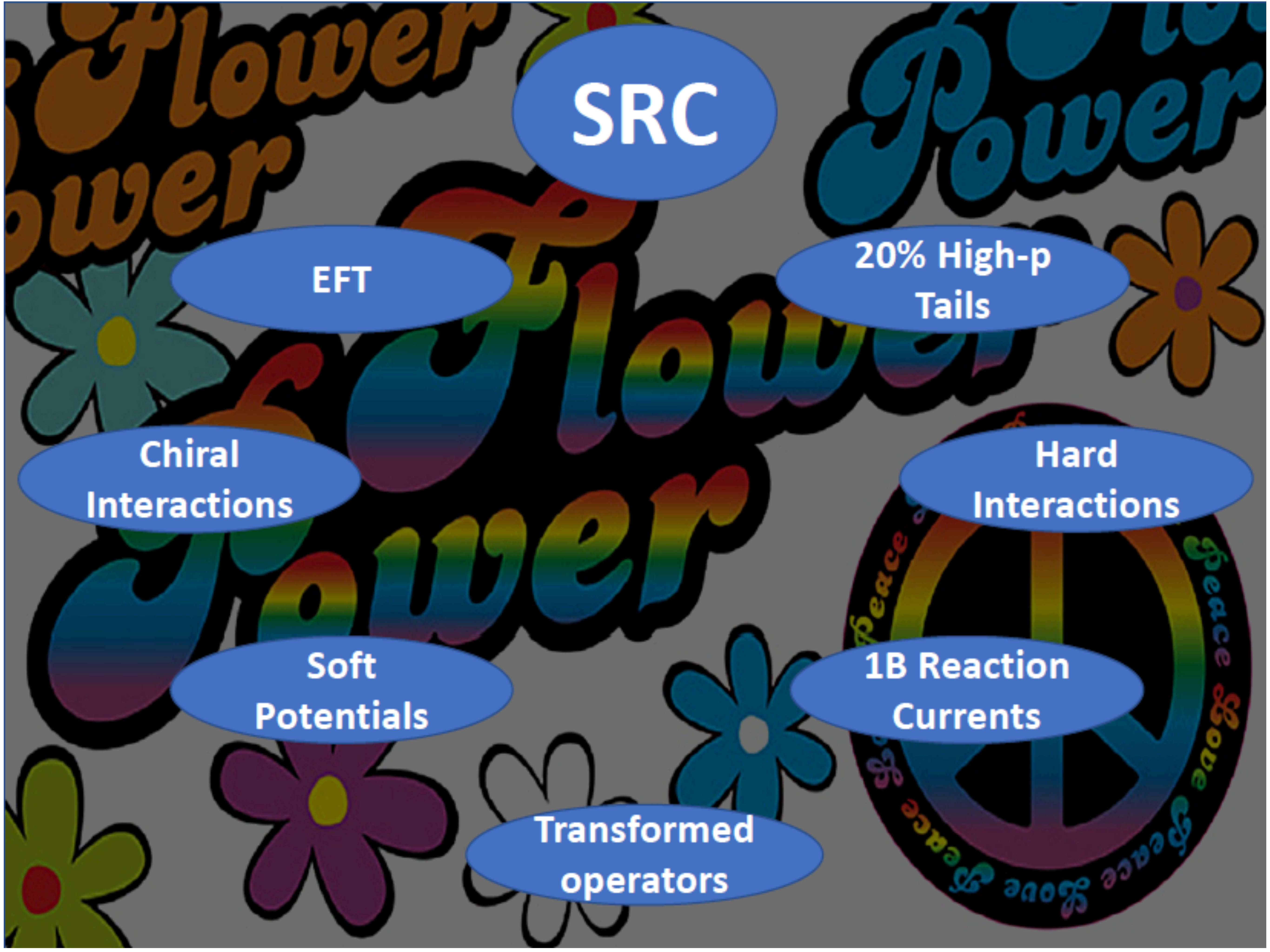
- Consider large q^2 near threshold (small p′) for θ=0 in **low-resolution** picture (COM frame of outgoing np)



no large relative momentum in evolved deuteron wf

1-body current makes no contribution

∴ 2-body current mostly stops the low-relative momentum np pair


SRC
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Some questions…

Can we use RG/OPE to connect high- and low-resolution pictures? (E.g., SF's in low-resolution shell model picture and SRCs in high-resolution picture)

How do interpretations vary with resolution scale? FSI? Ease of calculations (simple wf's + complicated currents vs. complicated wf's + simple currents)?

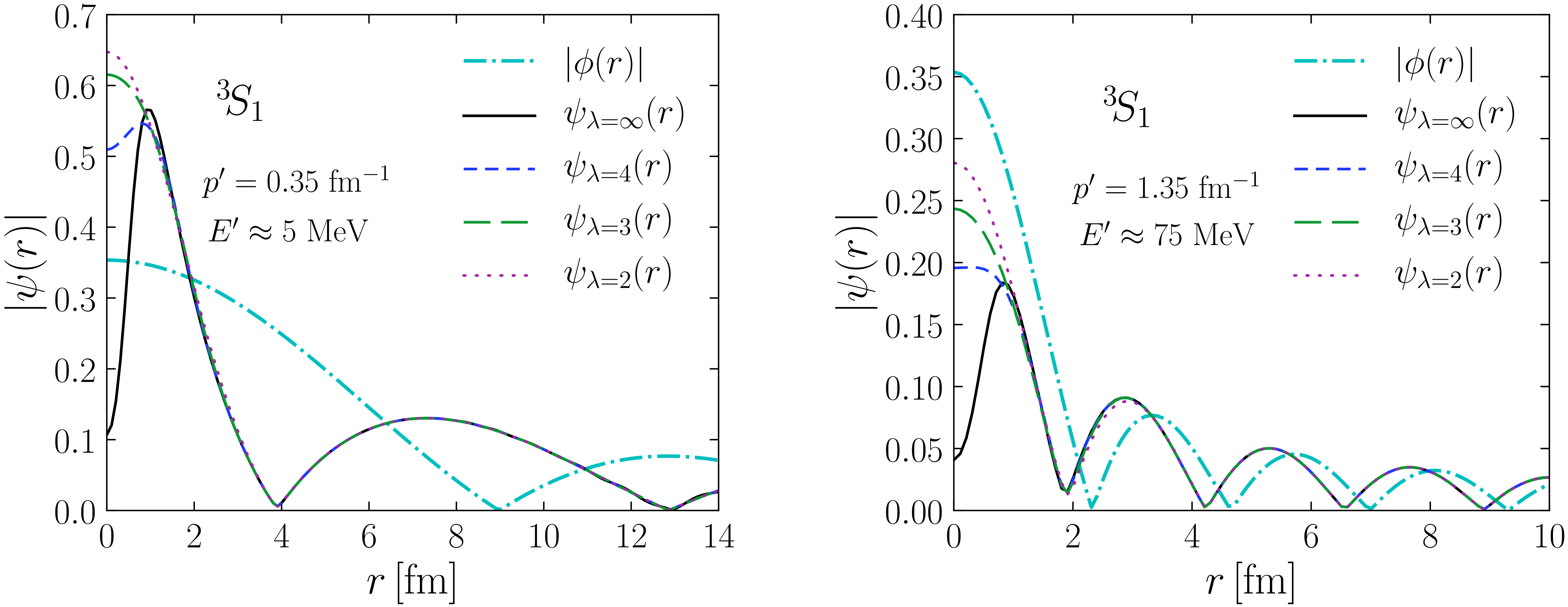
Can we use OPE + SRC/high-q measurements to extend reach of low-resolution theories ?

Can we use simpler low-resolution wf's + OPE for to do high-q electron scattering in medium mass nuclei?

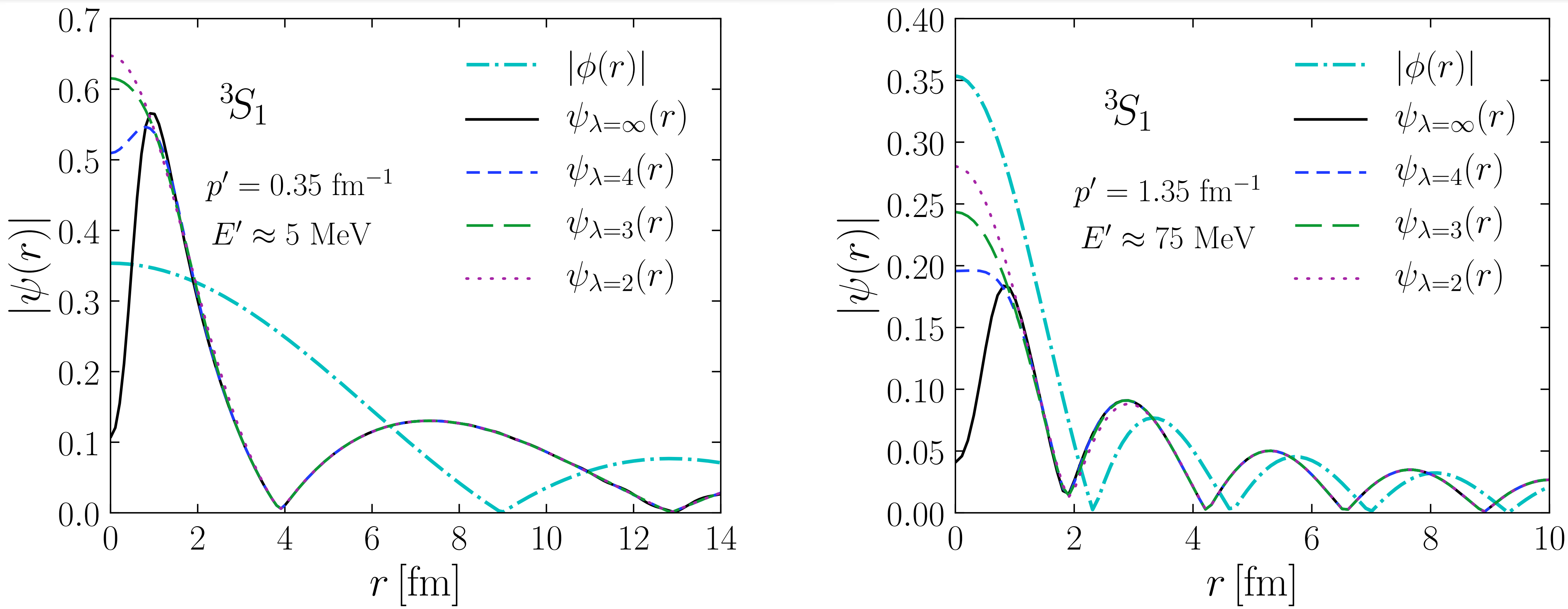
Can OPE be used to calculate "subleading" corrections to GCF (R. Weiss's talk) and LCA (J. Ryckebusch's talk) approaches?

Extras

Final-state wave function evolution

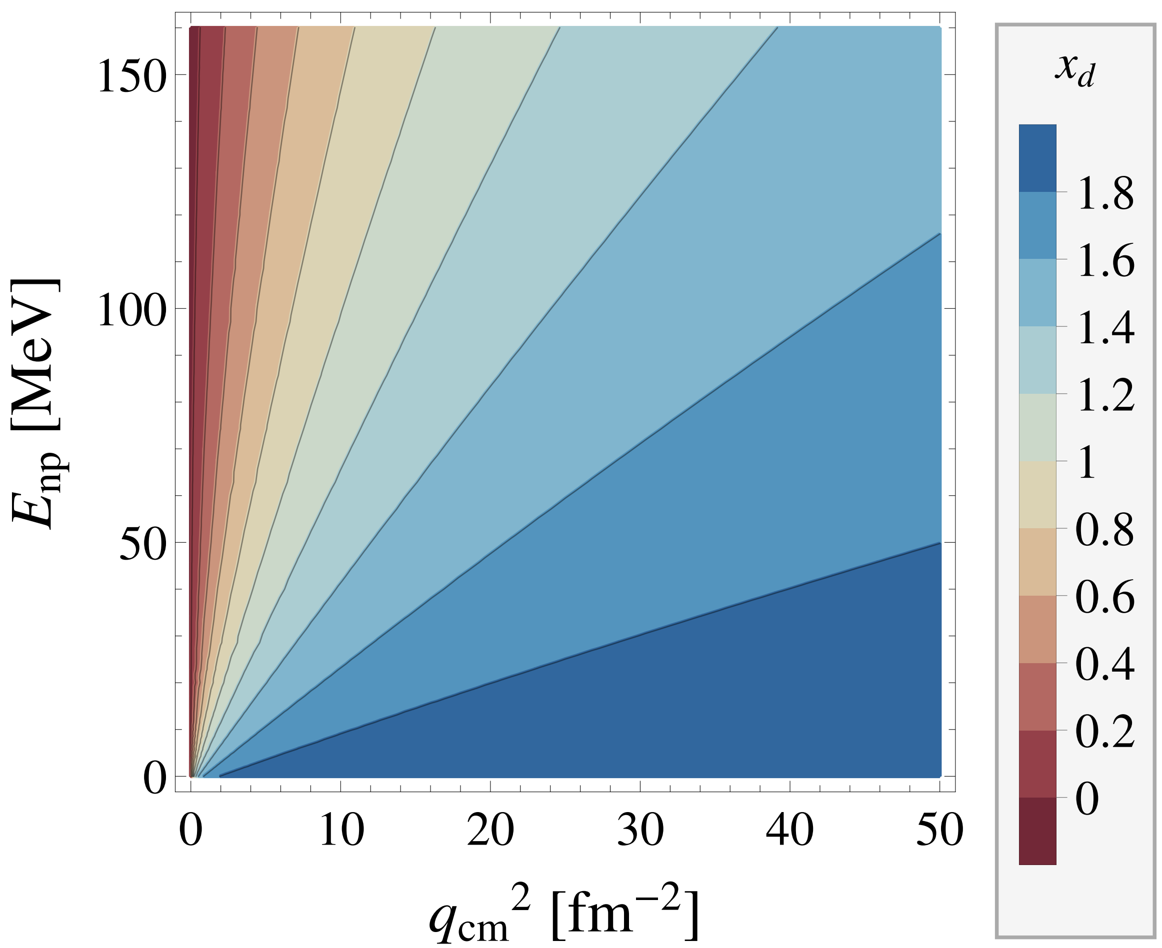


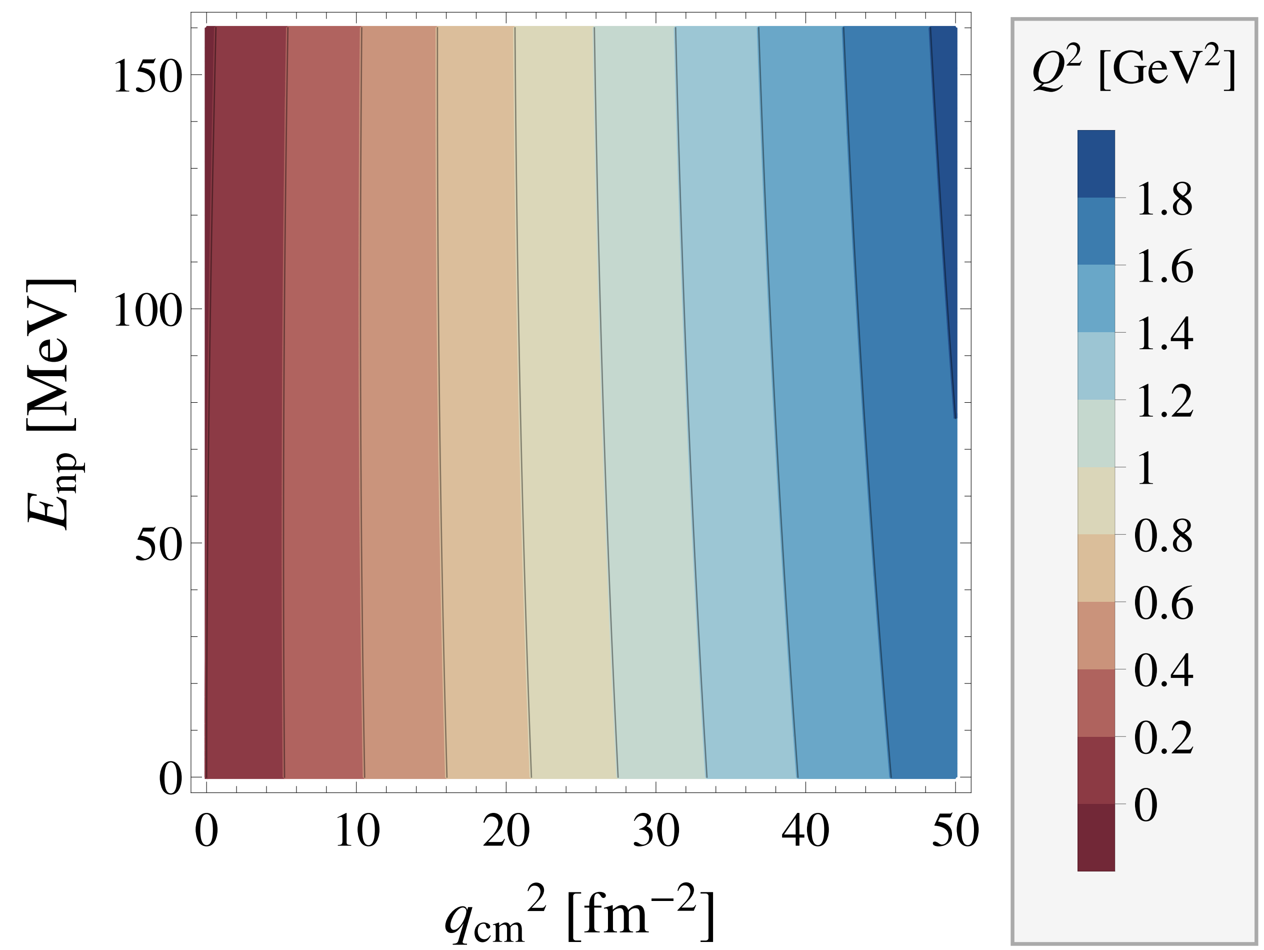
Final-state wave function evolution



- Correlation “wound” at small r smoothed out under evolution
- Long-distance tail invariant (phase shifts preserved)

Deuteron electrodisintegration kinematics





Wave function factorization

LO: $\psi_\alpha^{\Lambda_0}(\mathbf{q}) \approx \gamma(\mathbf{q};\Lambda) \int_0^\Lambda d^3p\, Z_\Lambda \psi_\alpha^\Lambda(\mathbf{p})$

state-independent ratio for well-separated scales

$$\frac{\psi_\alpha^{\Lambda_0}(\mathbf{q})}{\psi_\alpha^\Lambda(\mathbf{r}=0)} \sim \gamma(\mathbf{q};\Lambda)$$

$$|E_\alpha| \lesssim \Lambda^2 \quad |\mathbf{q}| \gtrsim \Lambda$$

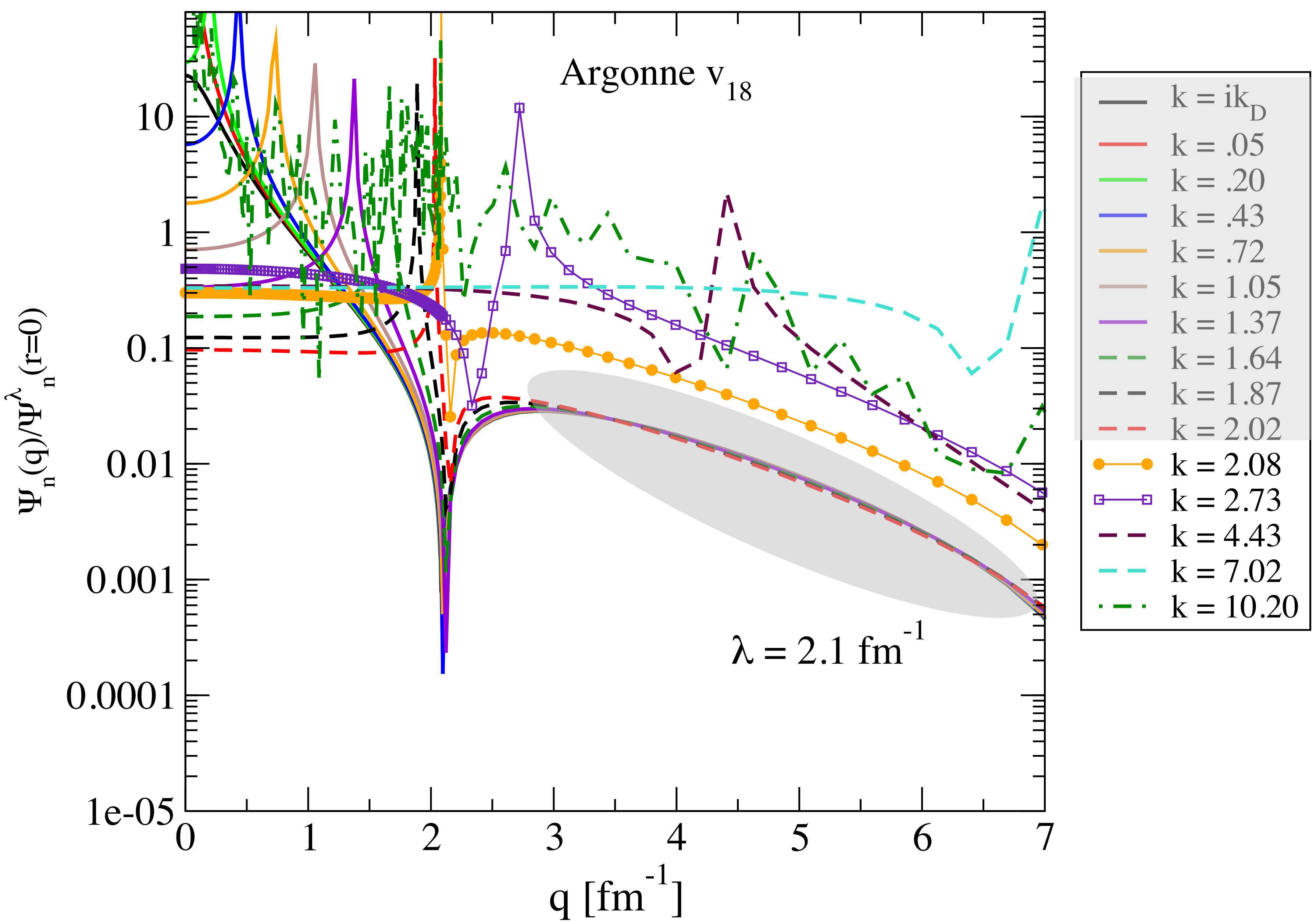
Wave function factorization

LO: $\psi_\alpha^{\Lambda_0}(\mathbf{q}) \approx \gamma(\mathbf{q};\Lambda) \int_0^\Lambda d^3p\, Z_\Lambda \psi_\alpha^\Lambda(\mathbf{p})$

state-independent ratio for well-separated scales

$$\frac{\psi_\alpha^{\Lambda_0}(\mathbf{q})}{\psi_\alpha^\Lambda(\mathbf{r}=0)} \sim \gamma(\mathbf{q};\Lambda)$$

$|E_\alpha| \lesssim \Lambda^2 \quad |\mathbf{q}| \gtrsim \Lambda$



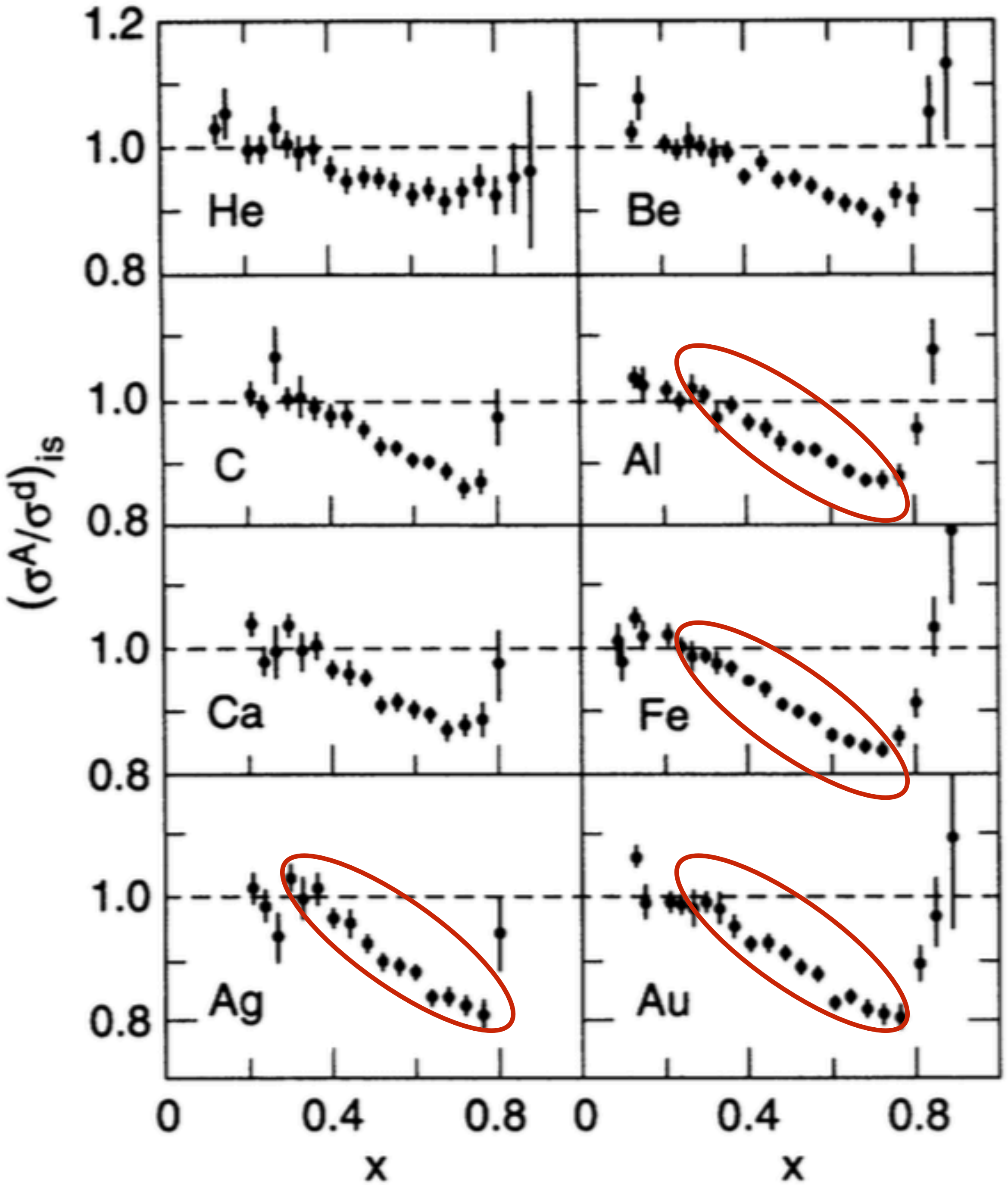
Scale dependence of short range correlations in medium-mass nuclei

in collaboration with

Nathan Parzuchowski
Dick Furnstahl

EMC Effect

electron-nucleus DIS



- Non-interacting limit ratio should be 1
- BE/A ~ 1% of M_N, Q
- 20% deviations from 1 = EMC effect

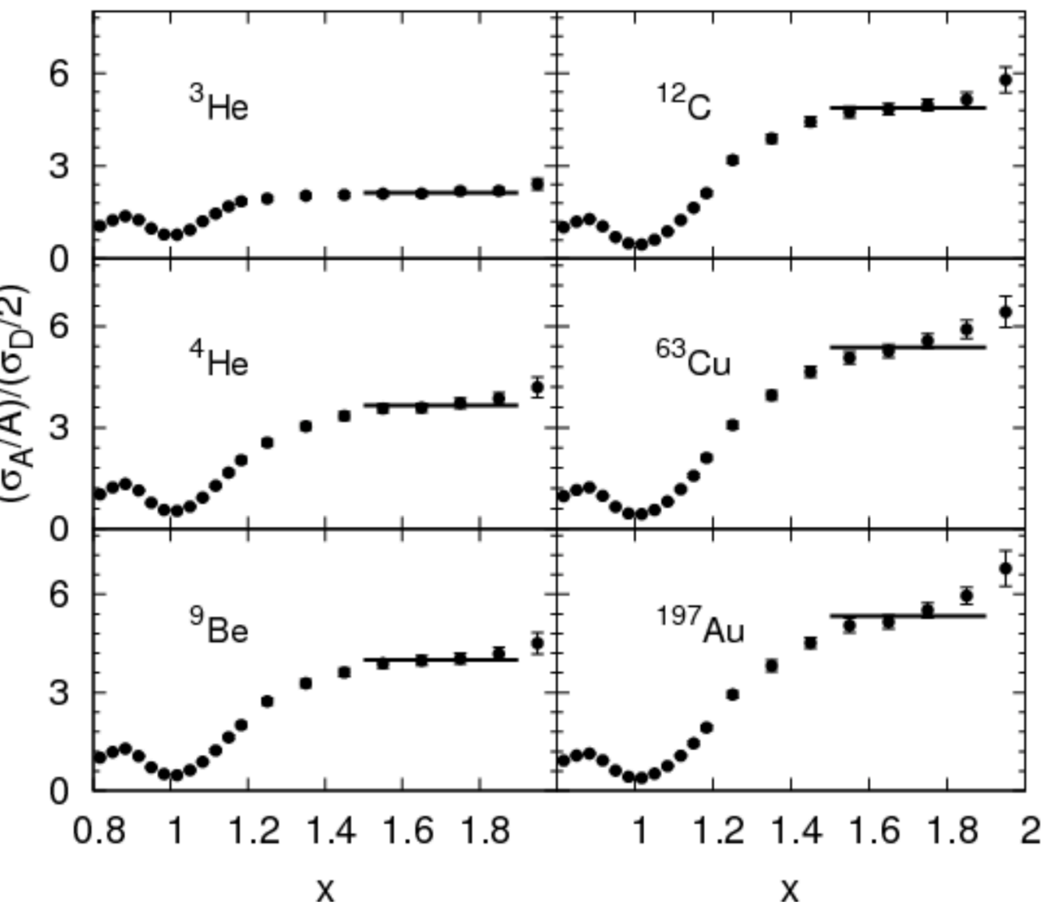
nucleon structure modified in-medium

Slope used to quantify size of effect

European Muon Collaboration, Phys. Lett. B 123 (1983)

Short-range correlations

Quasi-elastic (e,e'2N)



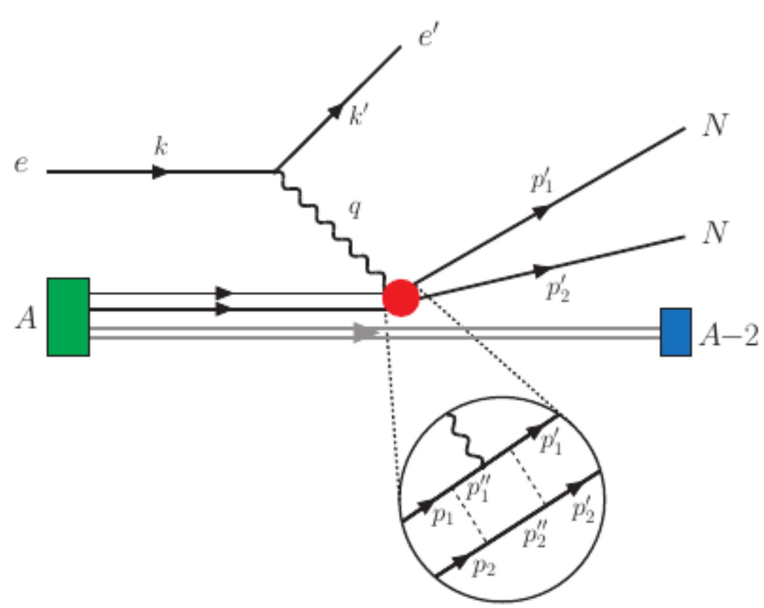
Fomin et al., Phys. Rev. Lett. 108 (2012)

plateaus for 1.5< x <2.0

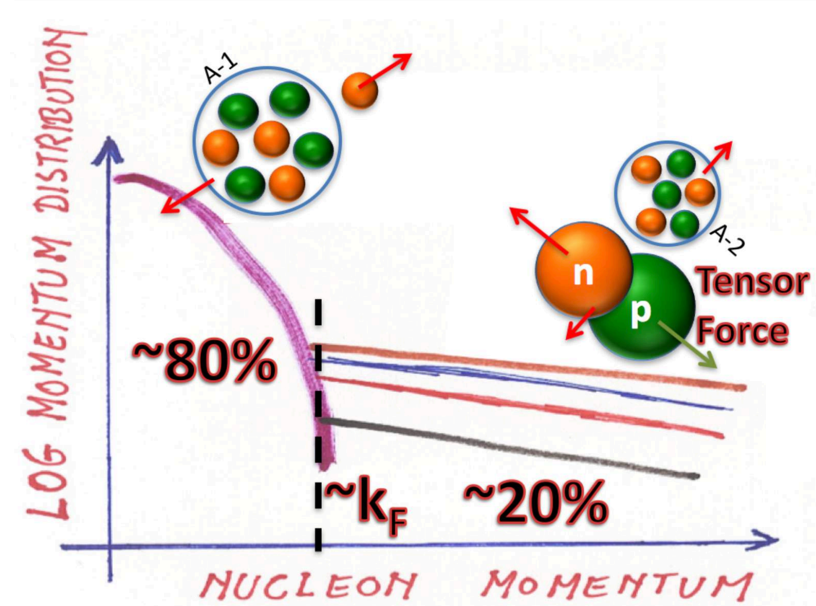
SRC interpretation:

NN interaction scatters pair $p_1,p_2 < k_F$ to intermediate-state momenta >> k_F which are then knocked out by photon

$$a_2(A) = \frac{2}{A}\frac{\sigma_A(x_B,Q^2)}{\sigma_d(x_B,Q^2)} \approx \frac{n_A(\mathbf{q} > k_F)}{n_d(\mathbf{q} > k_F)}$$

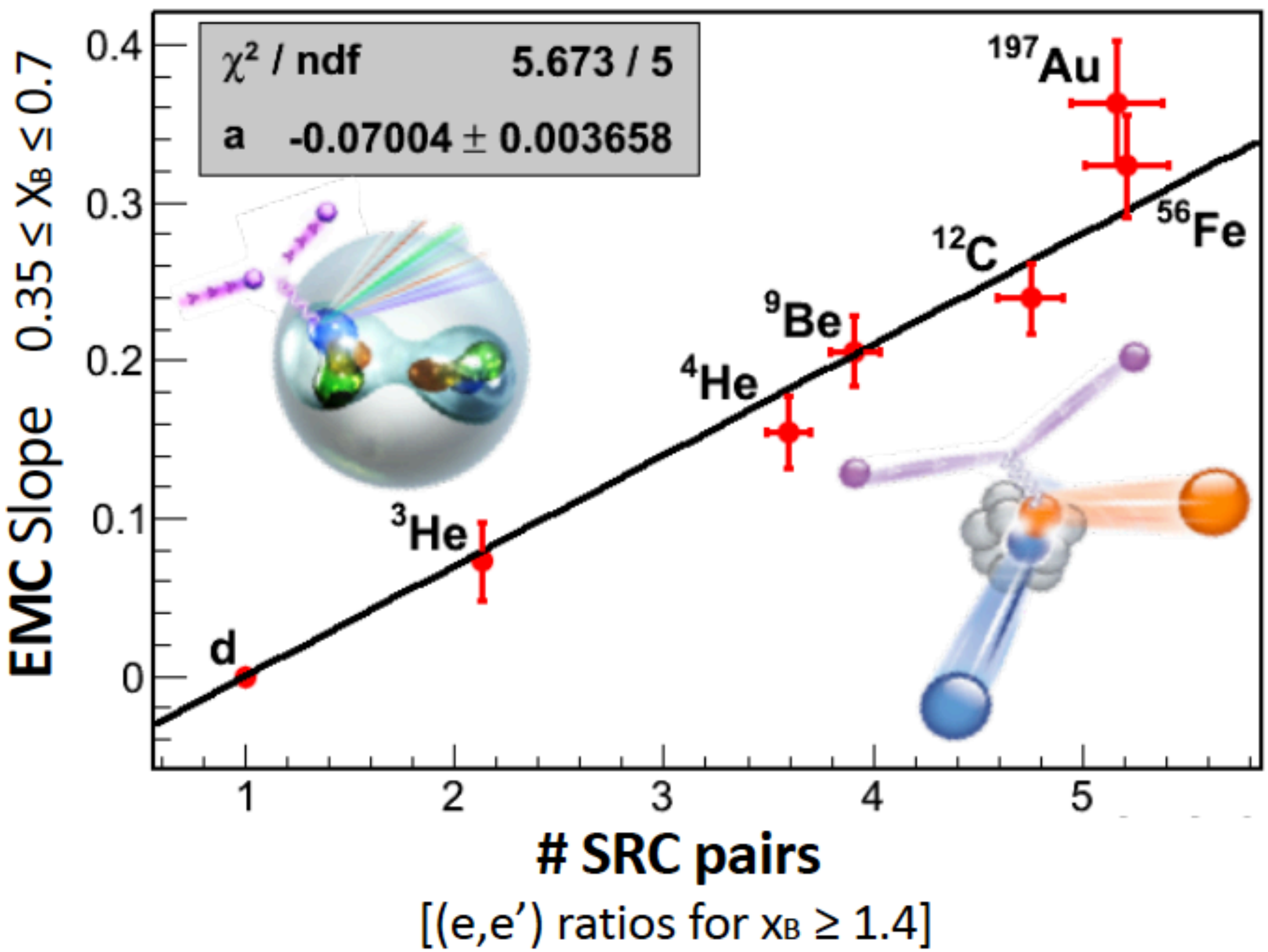


Hen et al., Rev. Mod. Phys. 89 (2017)



Empirical correlation of EMC effect

Hen et al., RMP (2017); Hen et al., IJMPE (2013); Hen et al., PRC (2012); Weinstein, Piasetzky, Higinbotham, Gomez, Hen, and Shneor, PRL (2011).

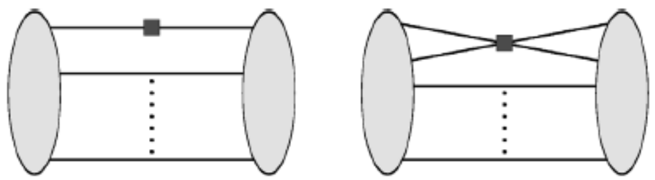


Why should 2 seemingly unrelated processes be linearly related?

EFT explanation

Chen and Detmold Phys. Lett. B 625 (2005)
Chen, et al., Phys. Rev. Lett. 119 (2017)

- Match isoscalar twist-2 quark operators to LO nucleon operators



$$\Longrightarrow \quad \langle x^n \rangle_A(Q) \approx \langle x^n \rangle_N(Q) \Big[A + \alpha_n(\Lambda) \langle A| : (N^\dagger N)^2 : |A\rangle \Big] + \cdots$$

DIS: $F_2^A(x,Q^2)/A \approx F_2^N(x,Q^2) + g_2(A,\Lambda) f_2(x,Q^2,\Lambda)$

$$g_2(A,\Lambda) = \frac{1}{2A} \langle A| : (N^\dagger N)^2 : |A\rangle_\Lambda$$

QES: $\sigma_A/A \approx \sigma_N + g_2(A,\Lambda)\sigma_2(\Lambda)$

$$a_2(A, 1<x<2) \approx \frac{g_2(A,\Lambda)}{g_2(2,\Lambda)}$$

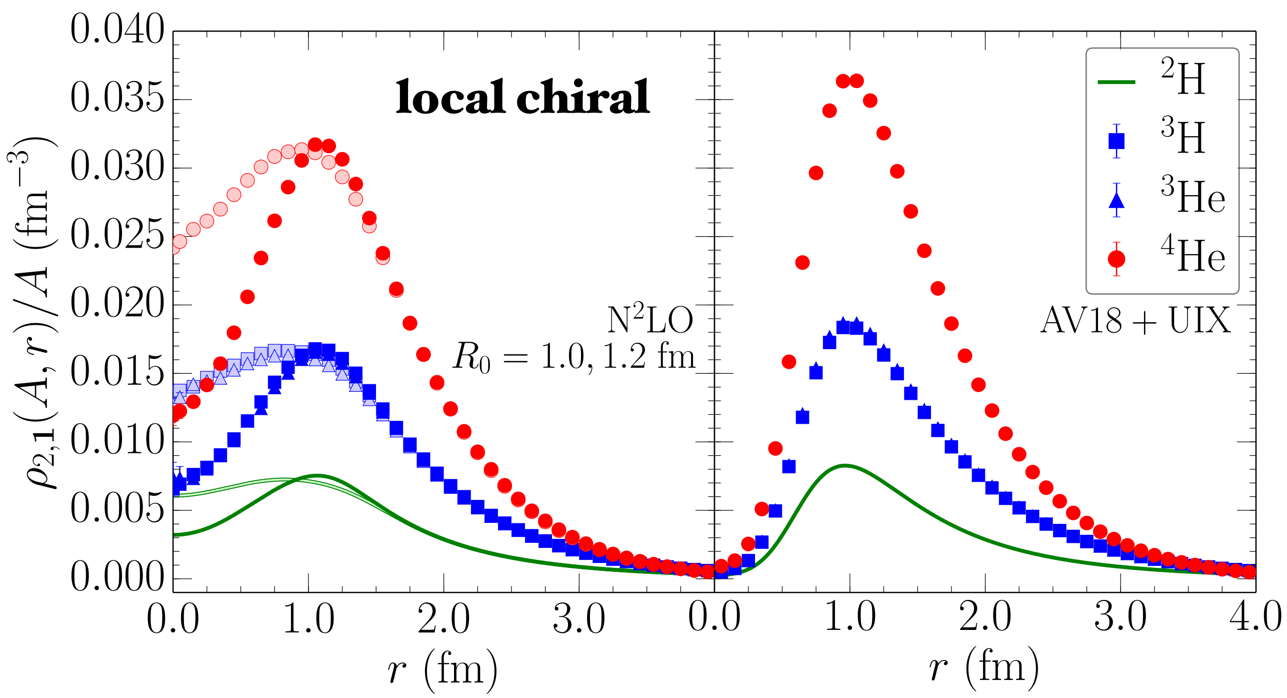
$$\frac{dR_{EMC}(A,x)}{dx} \approx C(x)\left[a_2(A) - 1\right]$$

scale dependence cancels in ratio!

linear relation between EMC/SRC!

QMC results for a_2

Chen, et al., Phys. Rev. Lett. 119 (2017)

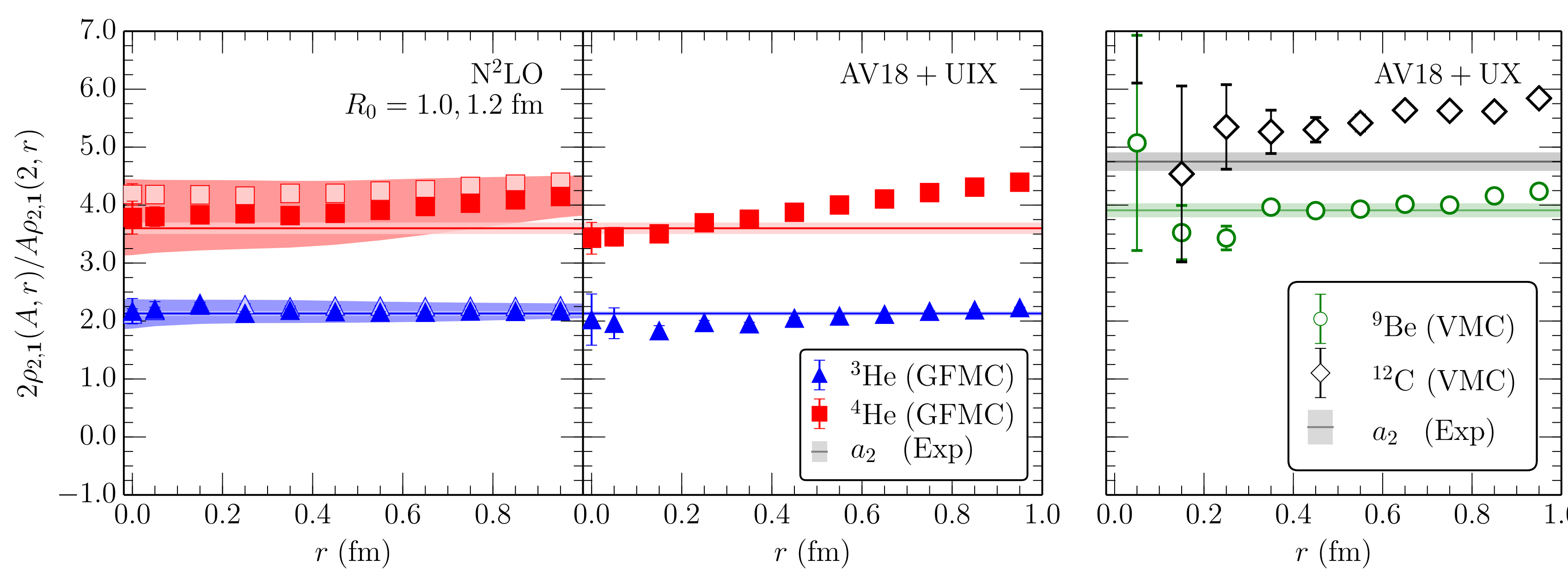


$$\rho_{2,1}(A,r) = \frac{1}{4\pi r^2}\langle\Psi|\sum_{i<j}^{A}\delta(r - |\mathbf{r}_i - \mathbf{r}_j|)|\Psi\rangle$$

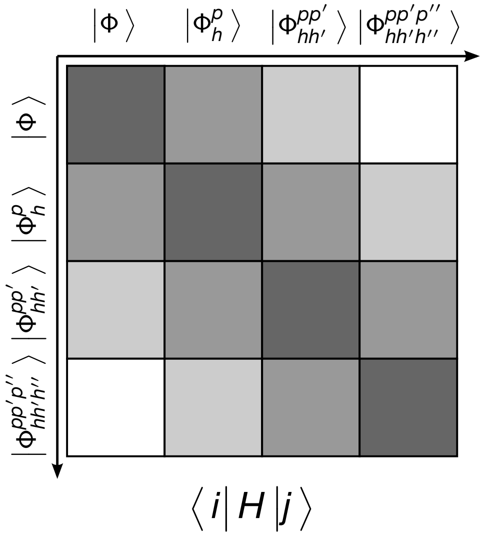
Scale and scheme dependent

…But ratio is ~ independent of scale and scheme!!

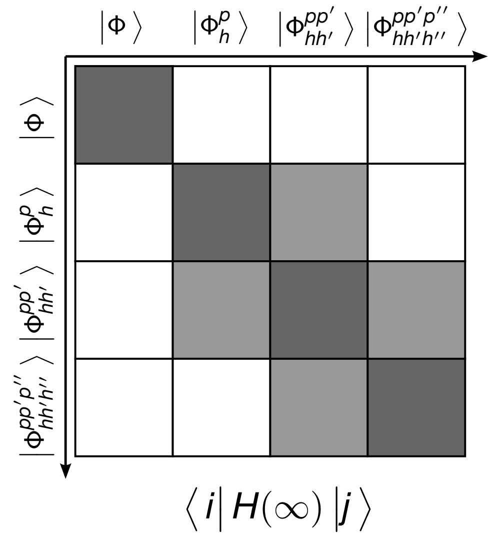
$$a_2(A) = \frac{2}{A}\frac{\rho_{2,1}(A,0)}{\rho_{2,1}(2,0)}$$



IM-SRG(2) calculations of a_2



$$\frac{dH(s)}{ds} = [\eta(s), H(s)]$$



$$\frac{d\hat{\rho}_{21}(s)}{ds} = [\eta(s), \hat{\rho}_{21}(s)]$$

$$\hat{\rho}_{21}(s=0) = \frac{1}{2}\sum_{\alpha,\beta}\int d\mathbf{R}\, N_\alpha^\dagger N_\beta^\dagger N_\beta N_\alpha$$

$$\langle\Psi_0|\hat{\rho}_{21}|\Psi_0\rangle = \langle\Phi|\hat{\rho}_{21}(\infty)|\Phi\rangle$$

Opportunities

access heavier nuclei (here up to A = 40)
access wider range of interactions**
(not limited to local interactions)

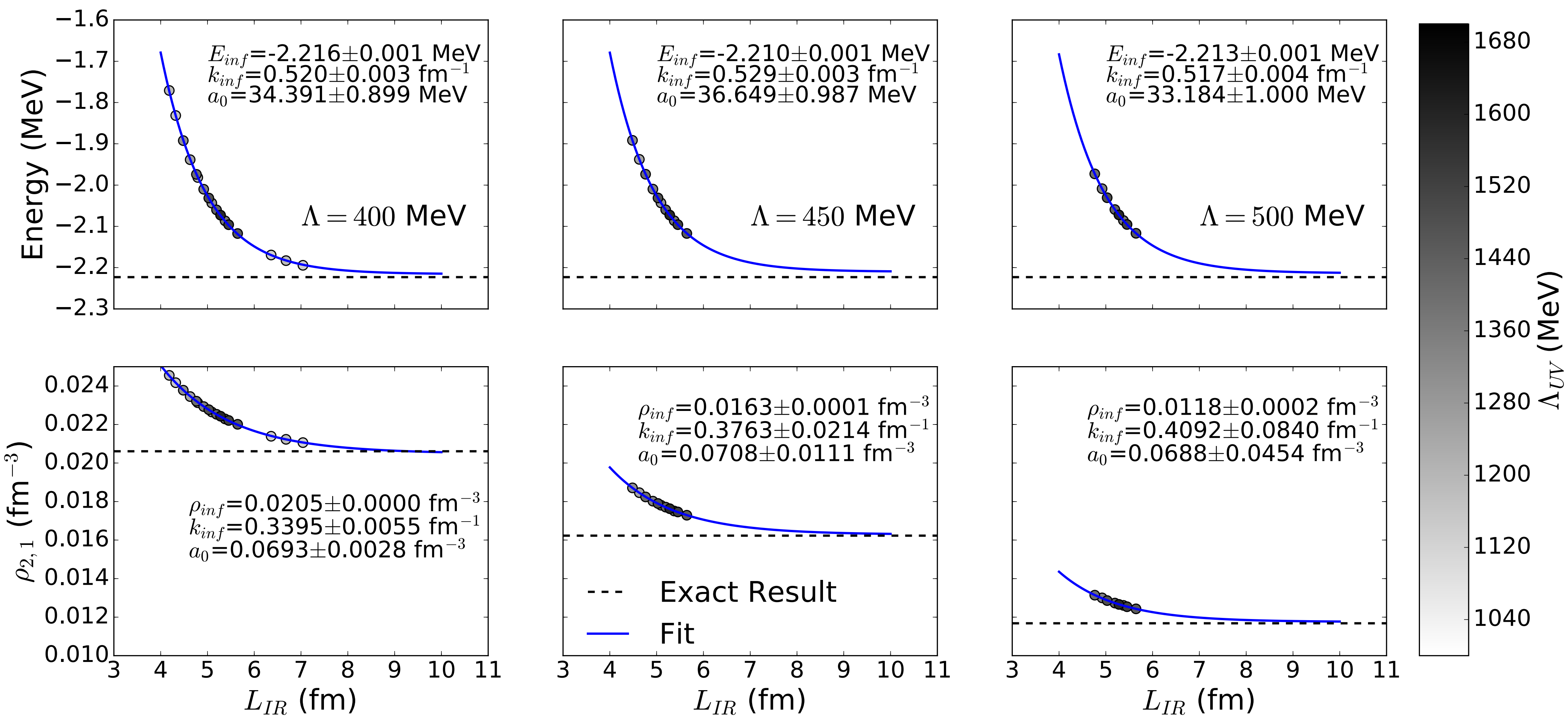
Challenges

QMC cleanly extrapolates to r = 0
(vs. implicit smearing due to truncated HO basis)
impact of IM-SRG(2) truncation errors?

** here we use the semi-local n4lo NN interaction of Reinert, Krebs, and Epelbaum

arXiv:1711.08821

IR extrapolations of $\rho_{2,1}$



Truncated HO basis ==> IR cutoff (box size L_{IR})
and UV cutoff

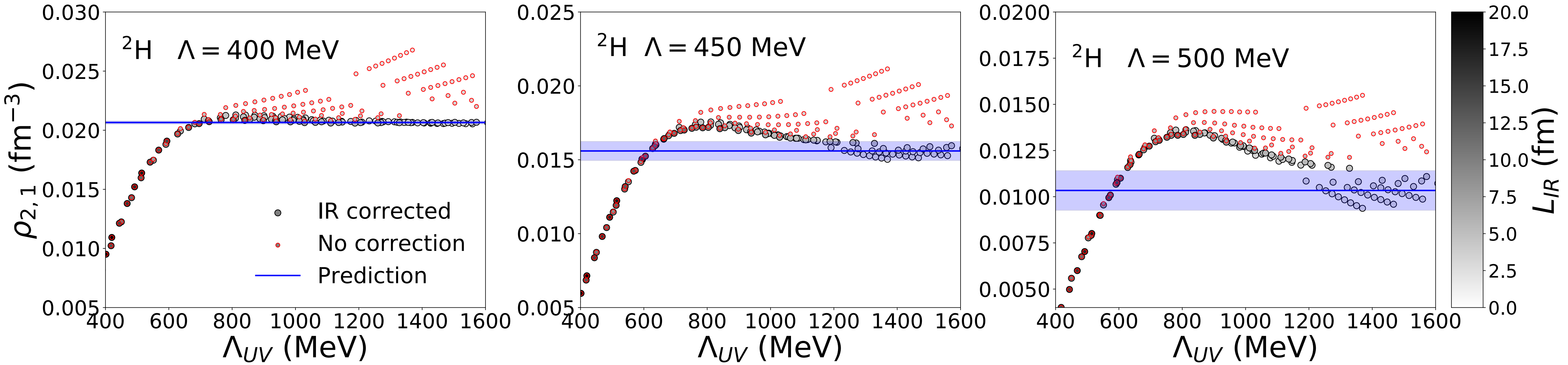
$$L_{IR} \sim \sqrt{2(2n+l)_{\max}+3}\; b$$

$$\rho_{2,1}(L_{IR}) = \rho_{2,1}(\infty) + a_0 e^{-k_\infty L_{IR}}$$

$$\Lambda_{UV} \sim \sqrt{2(2n+l)_{\max}+3}\; b^{-1}$$

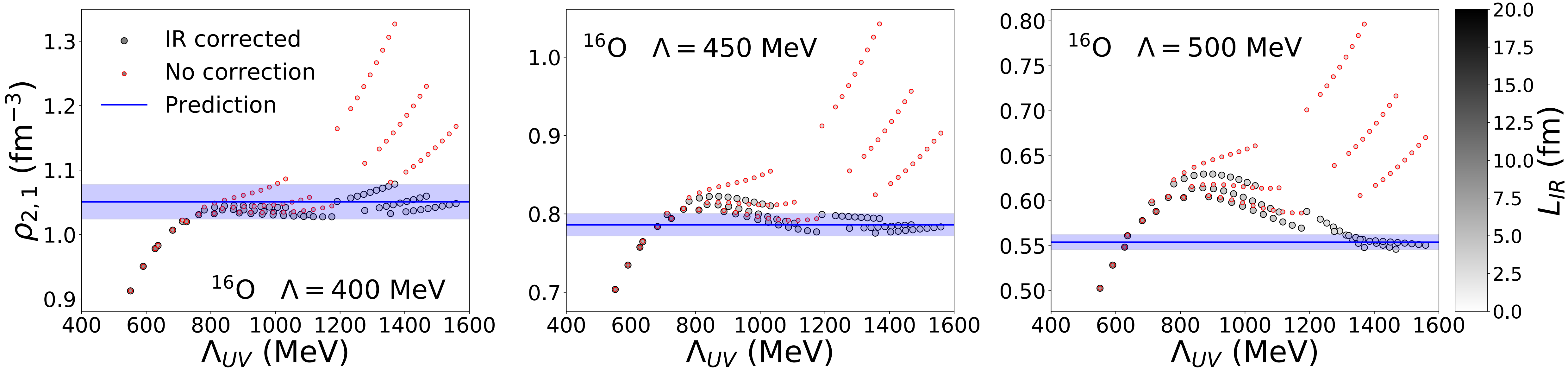
"motivated" by energy/radii formulae More et al. PRC87 (2013)

UV convergence of $\rho_{2,1}$



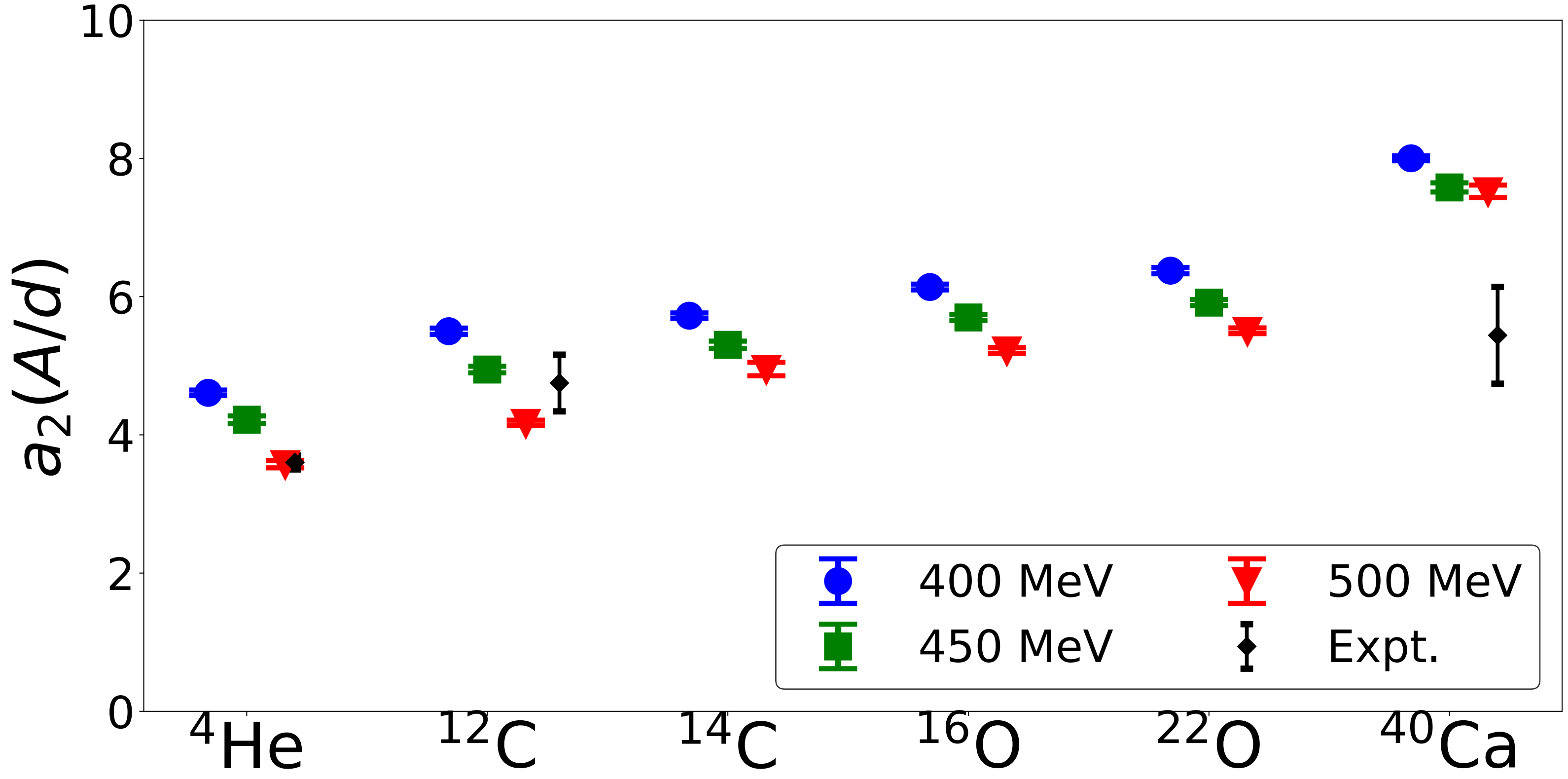
- No well-founded UV extrapolation formula
- UV convergence reasonable (w/IR correction added) for Λ= 400, 450 MeV
- 500 MeV convergence not so nice

UV convergence of $\rho_{2,1}$



- No well-founded (yet) UV extrapolation formula
- UV convergence not as clean for A > 2, not fully understood

Results for a_2



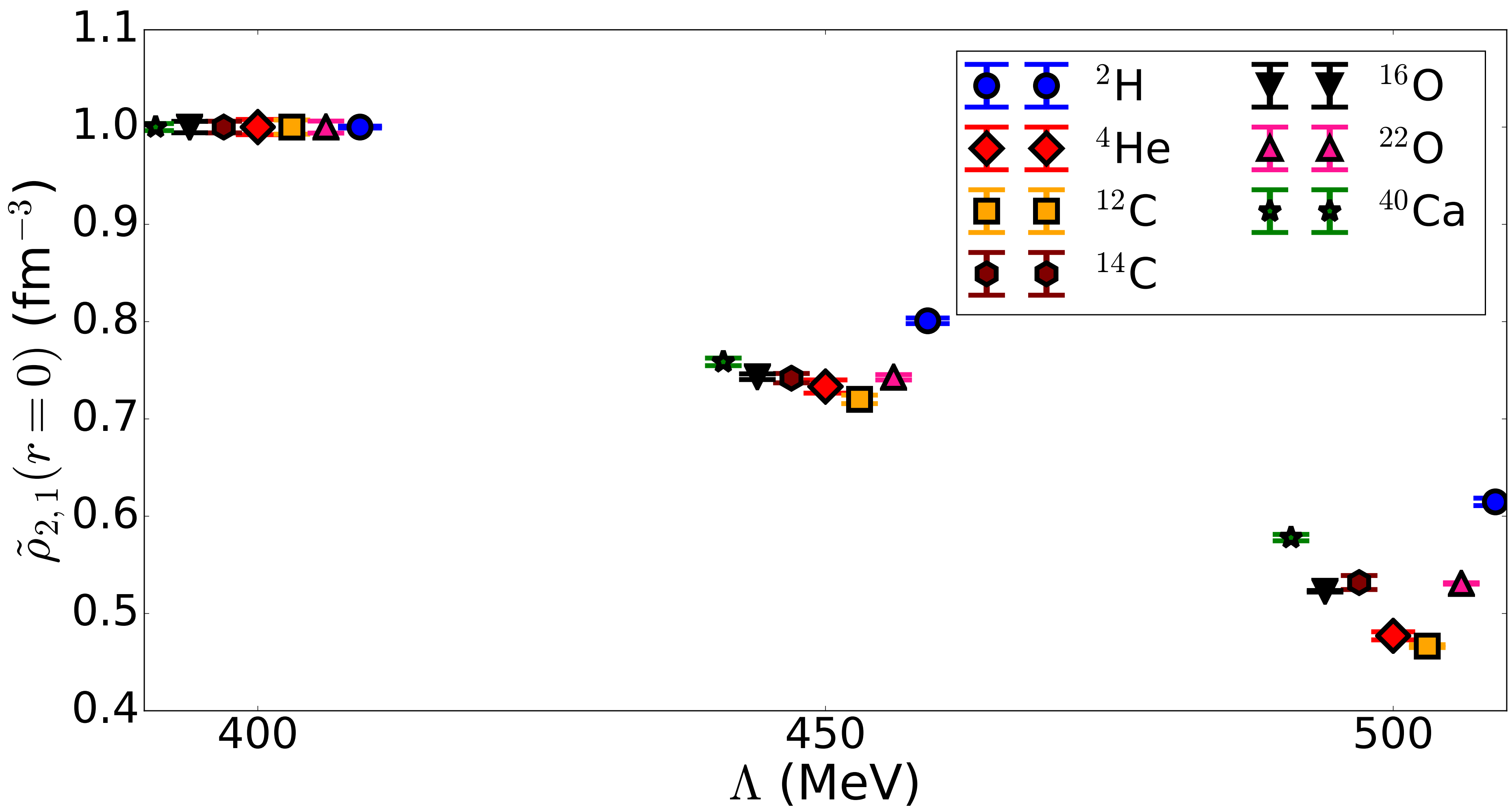
has IM-SRG(2) truncation errors

$$a_2(A/d) = \frac{2}{A}\frac{\rho_{21}(A)}{\rho_{21}(2)}$$

no many-body truncation errors (calculated in FCI)

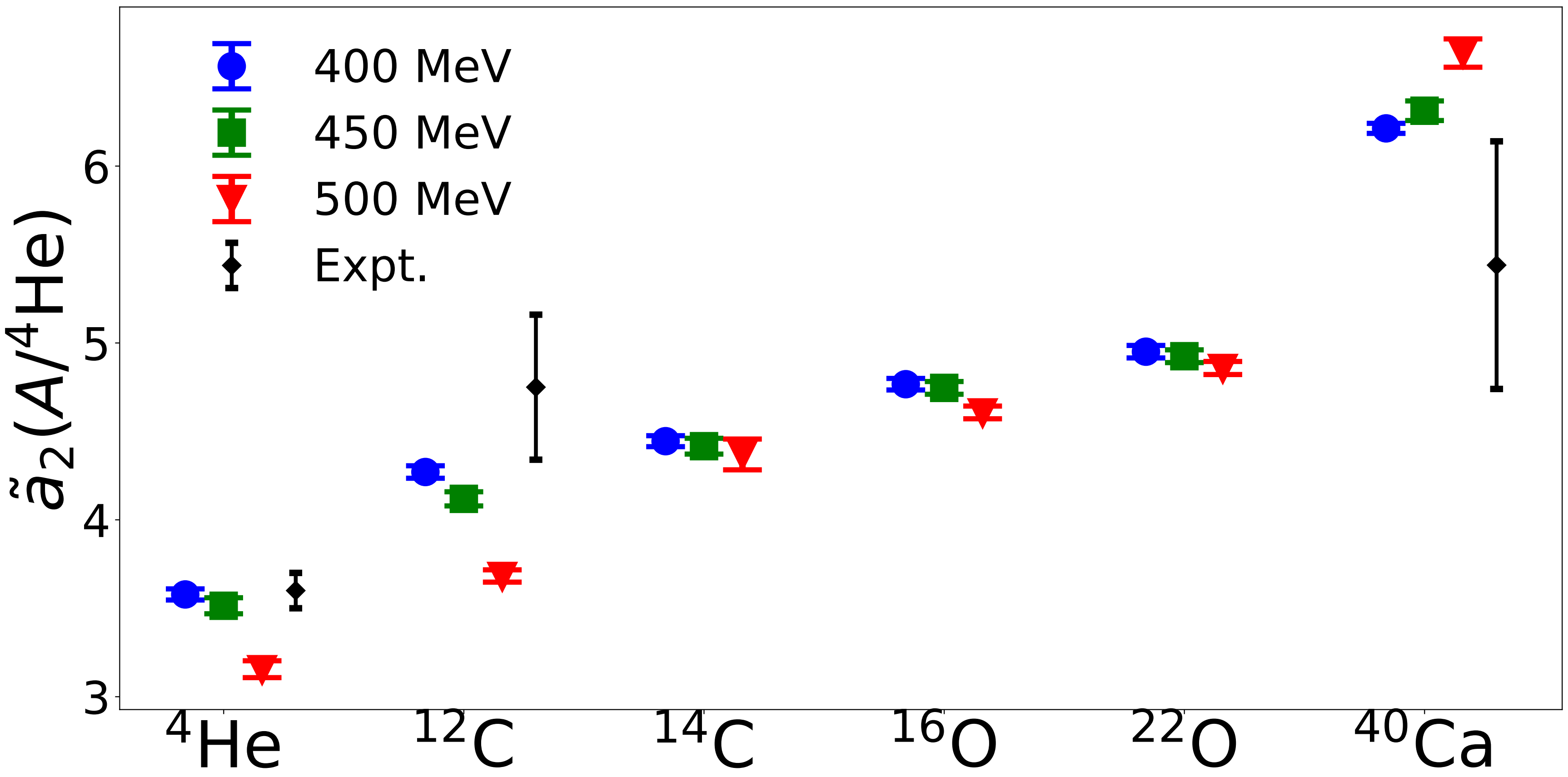
Need to disentangle UV/IR convergence and IM-SRG(2) truncation errors (and estimate EFT truncation error) before concluding if a_2 scale-independent

One possible hint



- ρ_{21} normalized to Λ=400. Different A-values should be equal
- A=2 systematically off from other A-values
- A=2 done in FCI, while A>2 in IM-SRG(2)
- Maybe better to normalize a_2 to ^{4}He instead ?

Results for a_2 (normalized to A=4)



Looks a little more systematic…

… but need better control on IR/UV convergence, IM-SRG(2) truncation errors, etc. to say more

Conclusions

- First IM-SRG calculations of SRC factor $a_2(A)$ carried out for closed-shell systems thru ^{40}Ca
- Results “not crazy” [reasonably scale-independent and close to experimental values], but much more work needed to disentangle systematics of IR/UV convergence and IM-SRG(2) truncation errors
- Near term todo list:
  - other EFT interactions (local, semi-local, non-local, different chiral orders, different cutoffs, etc.) and SRG-evolved ones to access wider range of resolution scales