Overview and Implications of Existing Experimental Constraints

Hadronic Parity Nonconservation
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Goal

- Test NC predictions of
  - pionless EFT
  - meson-exchange scheme

measurements to consider

- n-p spin rotation
- n-p circular polarization …
- n-d A_γ
- p-d A_L
- p-^{3}He A_L
- n-α spin rotation

Pioneless EFT N_C classification. Schindler and Springer

$$\begin{aligned}
\mathcal{C}^{(^3S_1-^1P_1)} &\sim N_c, \\
\mathcal{C}^{(^1S_0-^3P_0)}_{(\Delta I=0)} &\sim N_c, \\
\mathcal{C}^{(^1S_0-^3P_0)}_{(\Delta I=1)} &\sim N_c^0 \sin^2\theta_W, \\
\mathcal{C}^{(^1S_0-^3P_0)}_{(\Delta I=2)} &\sim N_c, \\
\mathcal{C}^{(^3S_1-^3P_1)} &\sim N_c^0 \sin^2\theta_W.
\end{aligned} \tag{33}$$

As before, the two isoscalar terms are not independent at LO in the large-N_c counting, but up to $1/N_c^2$ corrections are related by

$$\mathcal{C}^{(^3S_1-^1P_1)} = 3\,\mathcal{C}^{(^1S_0-^3P_0)}_{(\Delta I=0)}. \tag{34}$$

5-1 independent parameters. 4 experiments are needed to determine the 4 C's and compare with N_C predictions

Test N_C predictions of EFT

Pionless EFT can be applied to 4 experiments

$\vec{n}+p\rightarrow d+\gamma \;\; A_\gamma$ done

$\vec{n}+p\rightarrow d+\gamma \;\; P_\gamma$ not done

$\vec{n}+p$ spin rotation not done

$\vec{p}+p$ longitudinal asymmetry done

from

$$A_\gamma = \left(-3.0 \pm 1.4\right)10^{-8}$$

$$C^{\left({}^3S_1-{}^3P_1\right)} \Big/ C_0^{\left({}^3S_1\right)} = \left(-7.4 \pm 3.5\right)10^{-11}\ \mathrm{MeV}^{-1}$$

Essential steps to test pionless EFT

- Measure
  - n-p spin rotation
  - One of
    - n+p->d+γ γ circular polarization
    - γ+d photodisintegration
    - Calculate ΔI=2 on the lattice
- The low-energy 2-body system is well controlled theoretically. The above campaign will yield an unambiguous set of C's

Meson-exchange picture

- 7 couplings correspond to the 7 P-odd rotational invariants that can be constructed from the momenta, isospins, and spins of the interacting pair of nucleons
- $h_{\pi,1}$, $h_{\rho,0}$, $h_{\rho,1}$, $h_{\rho,1}'$, $h_{\rho,2}$, $h_{\omega,0}$, $h_{\omega,1}$
- PV observables are written as sums of meson couplings and dimensionless expansion coefficients

Existing experiments and their meson-exchange coefficients

i	Exp	Value	err	$h_{\pi,1}$	$h_{\rho,0}$	$h_{\rho,1}$	$h_{\rho,2}$	$h_{\omega,0}$	$h_{\omega,1}$
1	pp14Al	-0.98	0.2	0	0.0532	0.0532	0.0217	0.0488	0.0488
2	pp45Al	-1.57	0.23	0	0.0953	0.0953	0.0389	0.0896	0.0896
3	pp220Al	0.84	0.34	0	-0.0293	-0.0293	-0.0119	0.0089	0.0089
4	pαAl	-3.34	0.93	-0.55	0.1132	0.0484	0.	0.0909	0.0776
5	18F	0.	4042.	3850.	0.	-338.8	0.	0.	-543.2
6	19H-	-735.	148.	-94.2	19.3881	8.2896	0.	15.5687	13.2908
7	npAγ	-0.3	0.14	-0.1105	0.	-0.0007	0.	0.	0.002
8	181Ta	-52.	5.	-8.25	1.698	0.726	0.	1.3635	1.164
9	175Lu	550.	50.	93.5	-19.244	-8.228	0.	-15.453	-13.192
10	41K	200.	40.	25.85	-5.3204	-2.2748	0.	-4.2723	-3.6472
11	n3He	0.1	0.1	-0.1892	-0.0364	0.0193	-0.0006	-0.0334	0.0413

All expressions use AV18 potential

4, 6, 8, 9, and 10 determine the same combination

Same for 1 and 2

There are 6 independent quantities and 6 couplings.

Error in h_j from experiment i is ~ $\sigma_i / a_{i,,j}$

Test Phillips N_C predictions

- Determine meson couplings from least squares fits to data
- Compare ratios of couplings to Phillips' N_C predictions

$h_{\rho,0}$ and $h_{\rho,2}$ $\sim N_C^{1/2}$ $= 1.7$
$h_{\omega,0}$ $\sim N_C^{-1/2}$ $= .57$
$h_{\rho,1}'$ and $h_{\omega,1}$ $\sim \mathrm{Sin}(\theta_W)^2 N_C^{1/2}$ $= .38$
$h_{\pi,1}$ and $h_{\rho,1}$ $\sim \mathrm{Sin}(\theta_W)^2 / N_C^{1/2}$ $= .13$

Note that heavy meson couplings are suppressed by hard core while π coupling is not

Small errors in theory or measurement of large ΔI=0 and 2 couplings will impact the small ΔI=1 couplings.

Note 2 tiers for ΔI=1 and ΔI=0.

Fit experiments to 6 parameters ($h_{\rho 1}$' not included because no published evaluation exists)

m/ΔI	value	error
$f\pi$	2.37885	1.10002
$f\rho 0$	-35.9852	8.40715
$f\rho 1$	20.4385	20.9224
$f\rho 2$	-25.649	39.6392
$f\omega 0$	20.9751	10.491
$f\omega 1$	-11.3571	8.30543

$\chi 2$/DOF= 6.99745/6

The large coupling, $h_{\rho,0}$ = -36, is well defined. Then we expect $h_{\rho,1}$'~$h_{\omega,1}$~8 and $h_{\pi,1}$~$h_{\rho,1}$~3

The unexpectedly large and poorly defined couplings may be caused by excluding $h_{\rho,1}$' or systematic uncertainties.

To stabilize the fits, set $h_{\rho,1}$=0.

Fit experiments to 5 parameters ($h_{\rho 1}'$ and $h_{\rho 1}$ excluded)

m/ΔI	value	error
fπ	1.54267	0.690903
fρ0	-31.9448	7.31933
fρ2	11.3833	11.583
fω0	15.7963	9.05287
fω1	-4.71565	4.77057

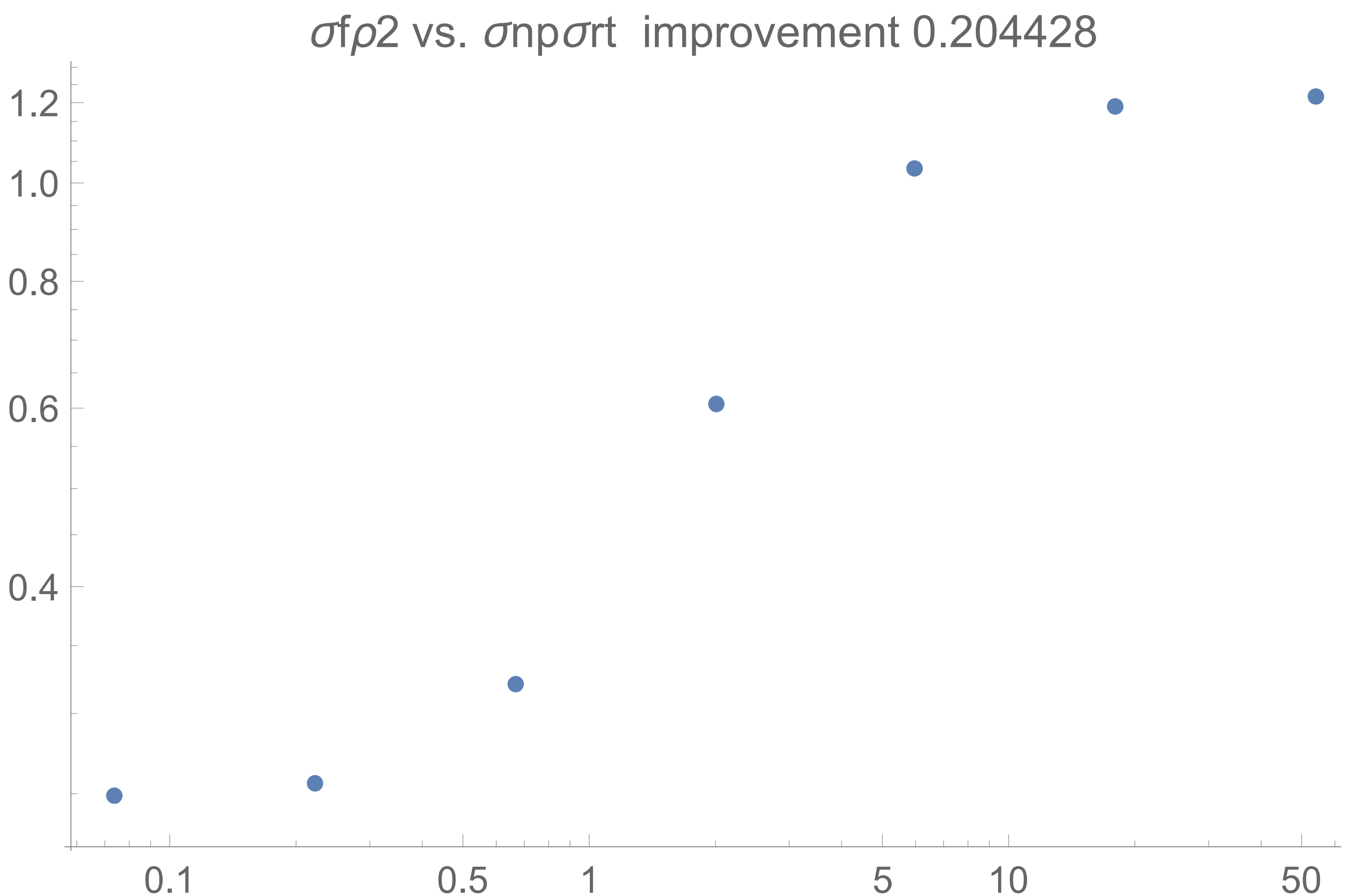
χ2/DOF= 7.95173/7

The large coupling, $h_{\rho,0}$ = -36->-32 , has not changed.
$h_{\pi,1}$ has not changed.
However, the uncertainties in $h_{\omega,0}$, $h_{\omega,1}$, and $h_{\rho,2}$ are large. How to reduce them?

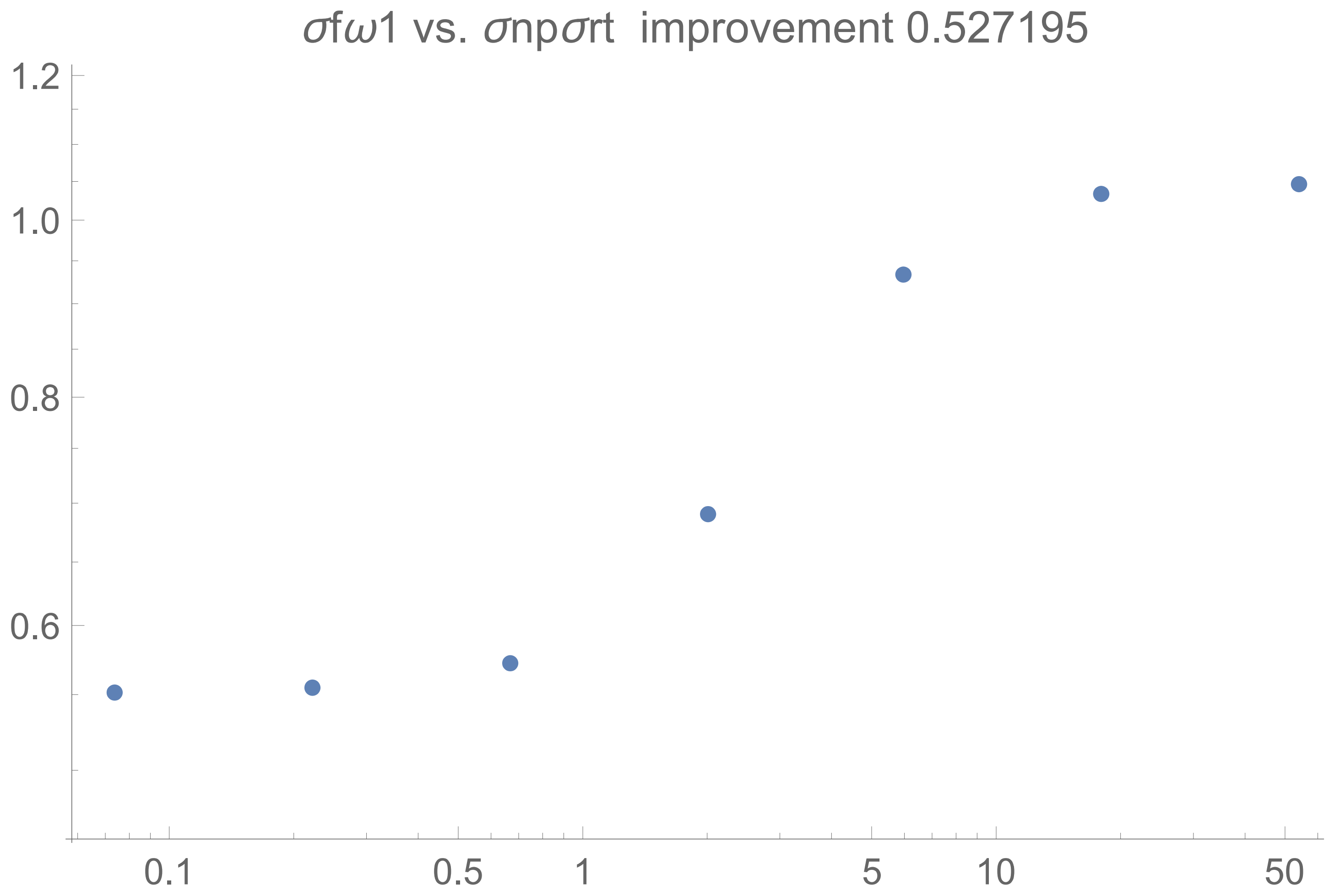
Which new measurements will have the largest impact?

- Add new measurements one at a time. Perform fits to the pseudo data and see how the uncertainties in $h_{\rho,2}$, $h_{\rho,1}$, $h_{\omega,0}$, and $h_{\omega,1}$ are reduced.
- [1.3] indicates that the value of the observable determined from the fit to existing data is 1.3 10^{-7}

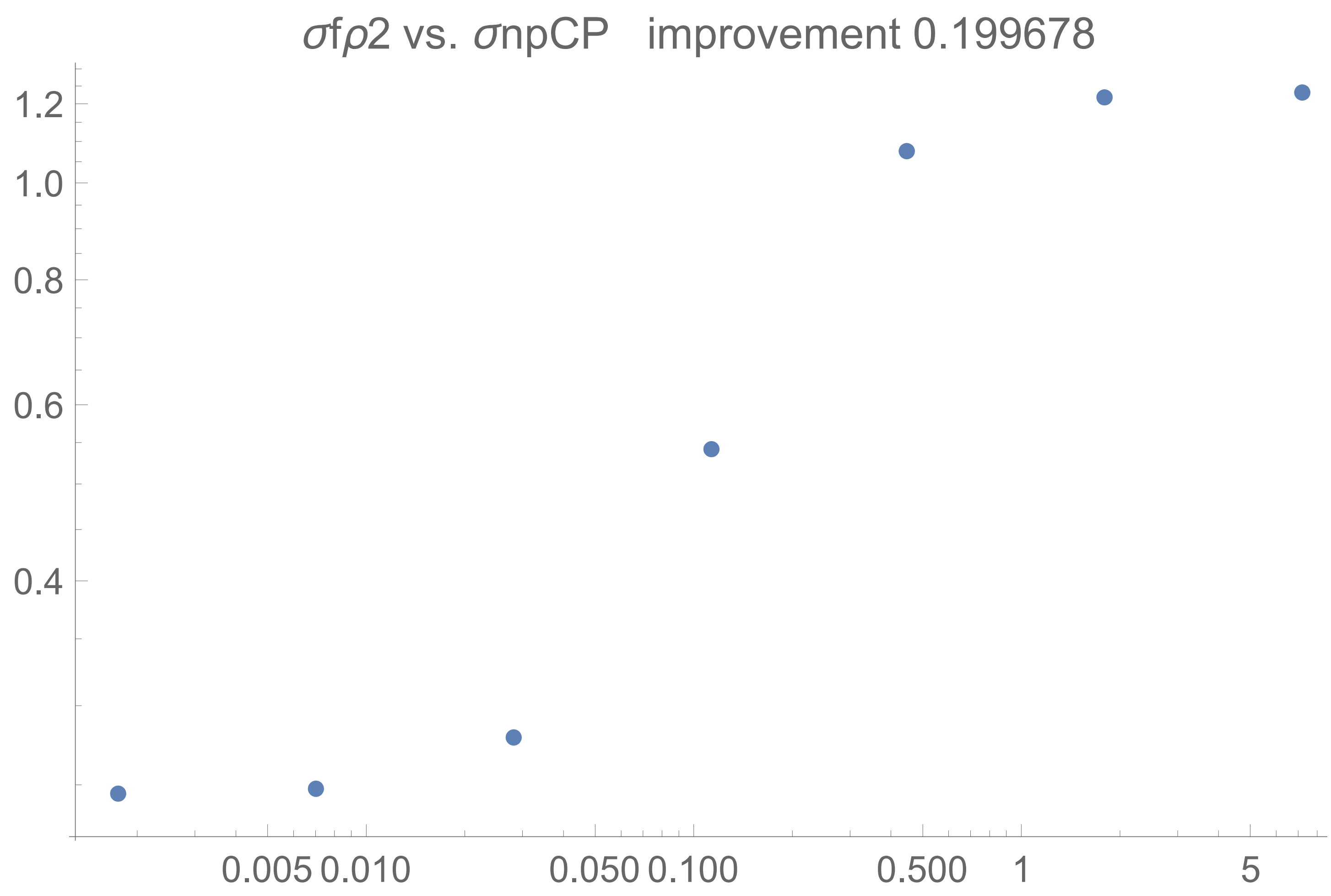
As σ npσr [1.3] is reduced, the σ $h_{\rho,2}$ is reduced by 5
Most of the gain occurs before σ = 1.



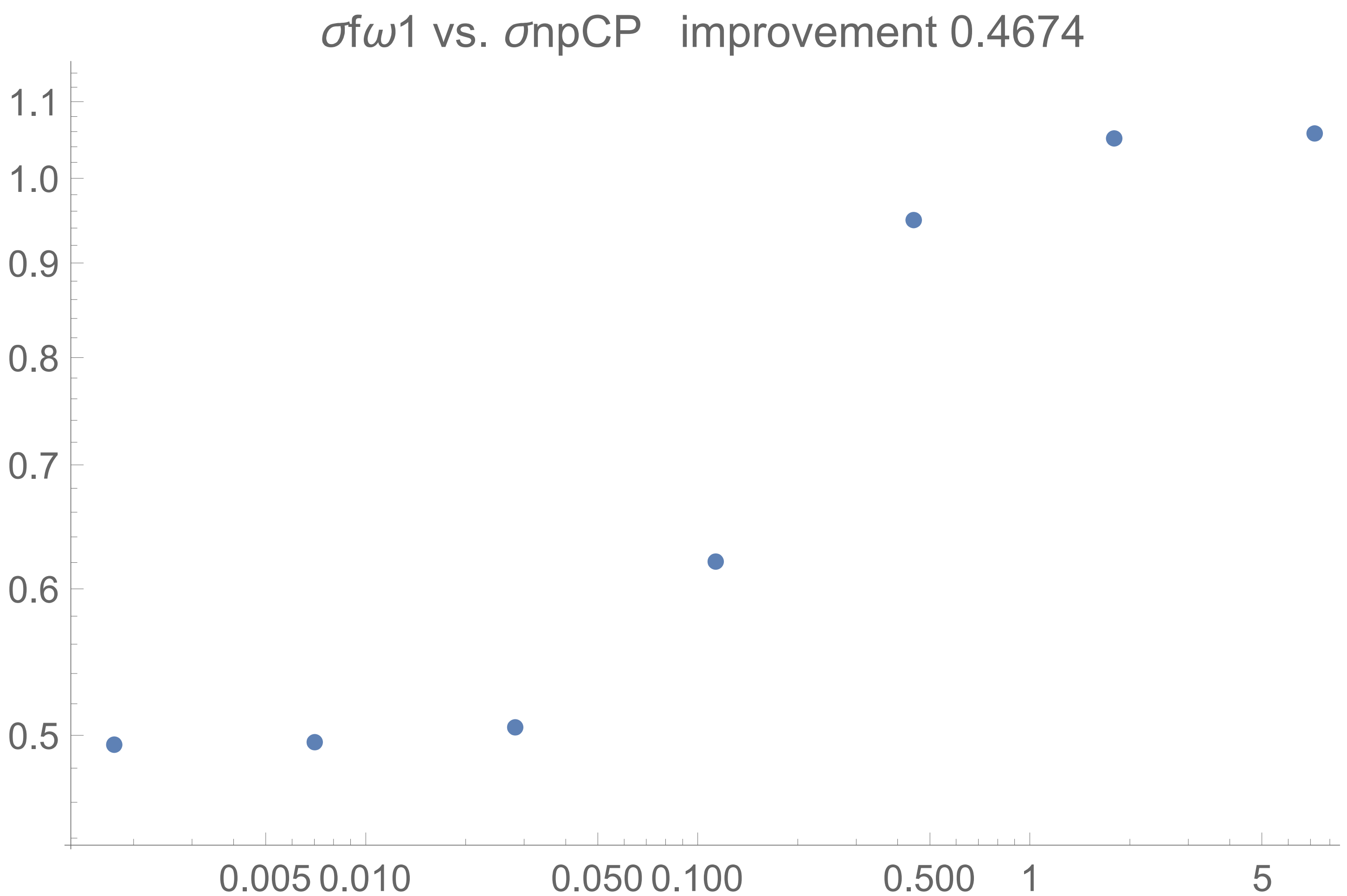
As σ npσr [1.3] is reduced, the σ $h_{\omega,1}$ is reduced by 2 Most of the gain occurs before σ = 1. No other couplings show much improvement.



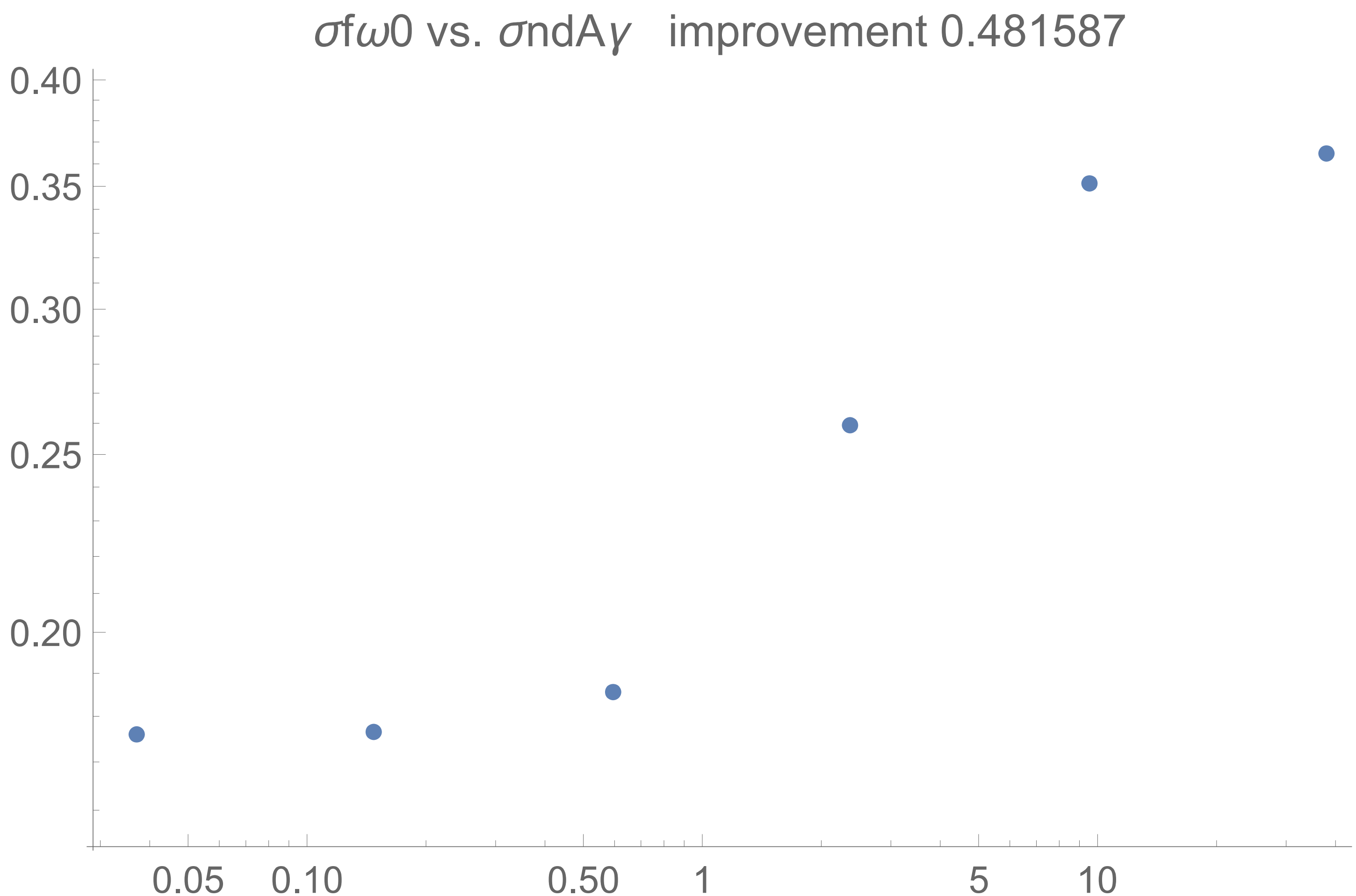
As σ npCP [.8] is reduced σ $h_{\rho,2}$ is reduced by 5. The reduction occurs before σ = .05



As σ nασr [1.7] is reduced σ $h_{\omega,1}$ is reduced by 2. The reduction occurs before σ = .07 (very small)



As σ ndAγ [17] is reduced the uncertainty in $h_{\omega,0}$ improves by 2. The improvement occurs before σ = 2.



Why is the uncertainty in hw,0 improved by measuring n+d->t+γ?

Expt	$ah_{\omega,0}/ah_{\rho,0}$
pp14Al	0.917293
pp45Al	0.940189
pp220Al	-0.303754
pαAl	0.803004
18F	Indeterminate
19H-	0.803004
npAγ	Indeterminate
181Ta	0.803004
175Lu	0.803004
41K	0.803004
n3He	0.917582

existing Experiments

Expt	$ah_{\omega,0}/ah_{\rho,0}$
npCP	-0.376471
ndAγ	0.32
npσrt	0.95122
n$\alpha\sigma$rt	0.803004
pd15Al	0.75

new experiments

Conclusions

- In order to test pionless EFT np spin rotation and np circular polarization, nd photo-desintigration, or $\Delta I=2$ on the lattice are necessary
- The above are also the crucial measurements to test the N_C treatment of the meson-exchange scheme
- Theoretical calculations should include $h_{\rho 1}'$ and consistently use the AV18 potential

More Conclusions

- Few-body calculations of nα spin rotation and pα A_L may demonstrate that the 1-body potential is not valid leading to better control of the 4 $\Delta I=1$ couplings