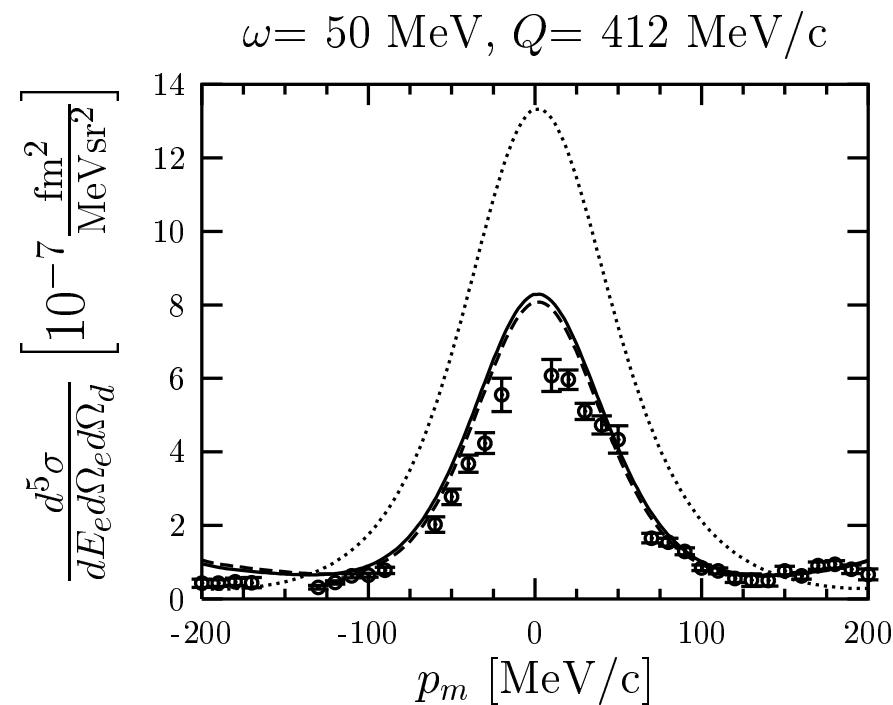


Asymmetries in electron-induced breakup of polarized ^3He

S. Širca, U of Ljubljana

MENU2010 | Williamsburg | 1 June 2010

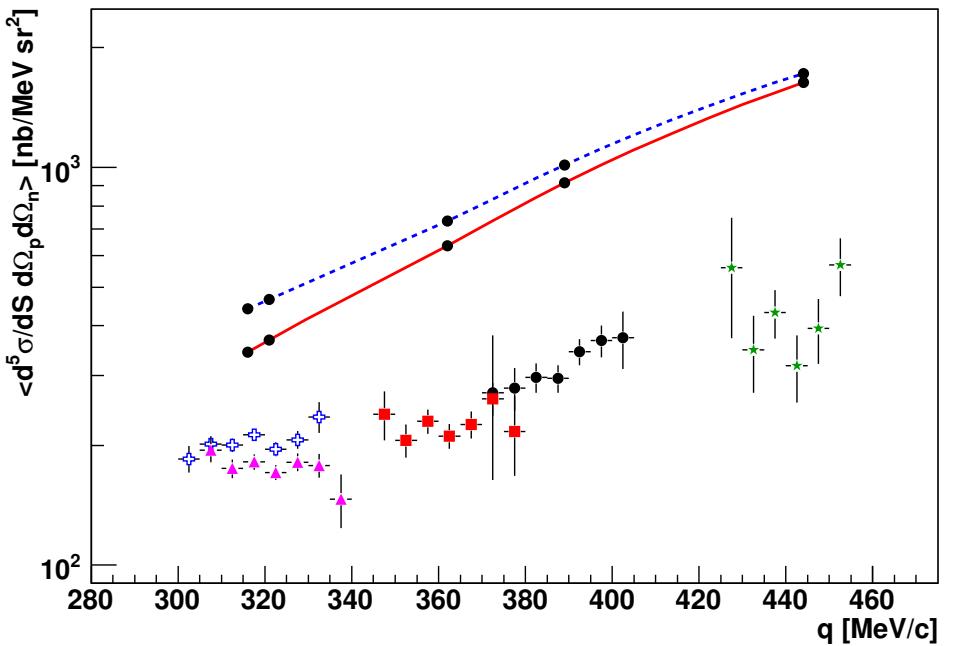
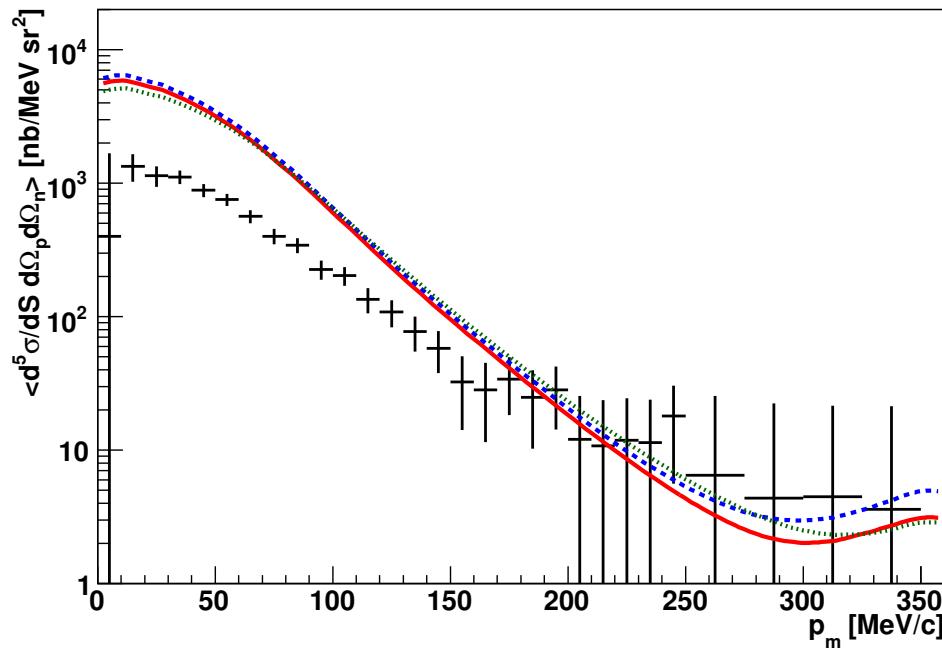
Introduction: “dramatic failure” (?) in ${}^3\text{He}(\text{e}, \text{e}'\text{d})$



- unpolarized XS, low p_{miss} !
- experimental confirmation would call for improvement in the currents
- possibly 3N forces in the continuum
- lack of simultaneous data on proton/deuteron angular distributions

Spaltro++ NPA **706** (2002) 403
Glöckle++ EPJA **21** (2004) 335

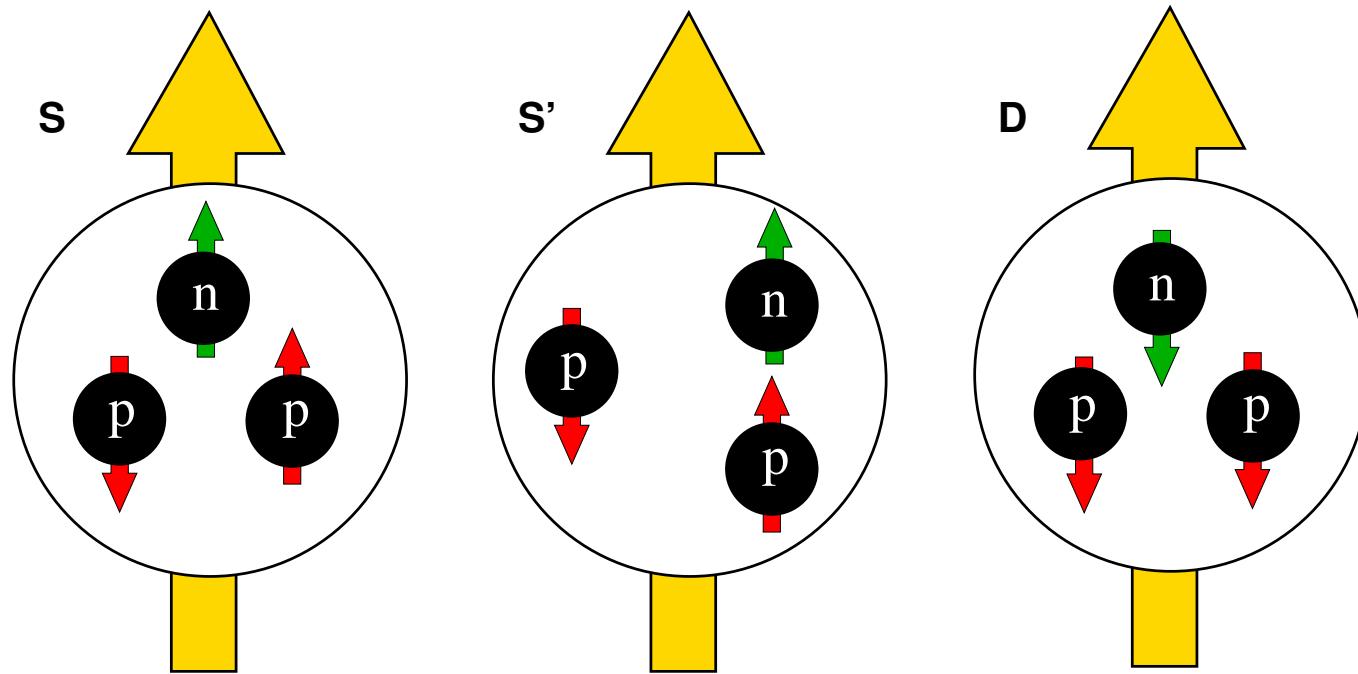
More trouble in unpolarized ${}^3\text{He}(\text{e}, \text{e}'\text{pn})$



- $\omega = 220, q = 375$
- typical overpredictions by a factor ≈ 5 at low p_{miss}
- opposite in $(\text{e}, \text{e}'\text{pp})$
- theory: incomplete MEC? need for IC? 3NF?

Middleton++ PRL **103** (2009) 152501

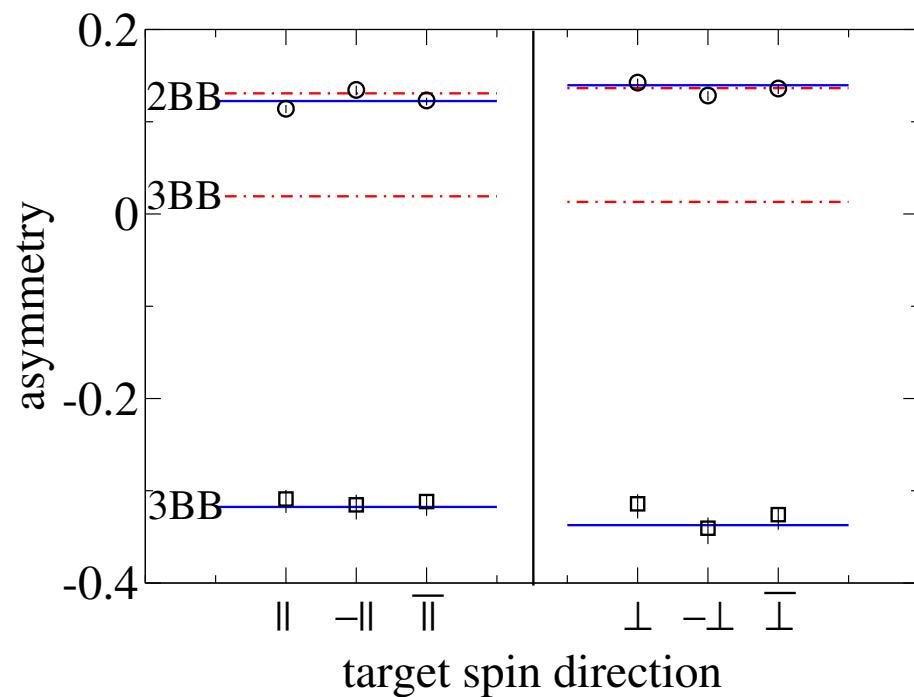
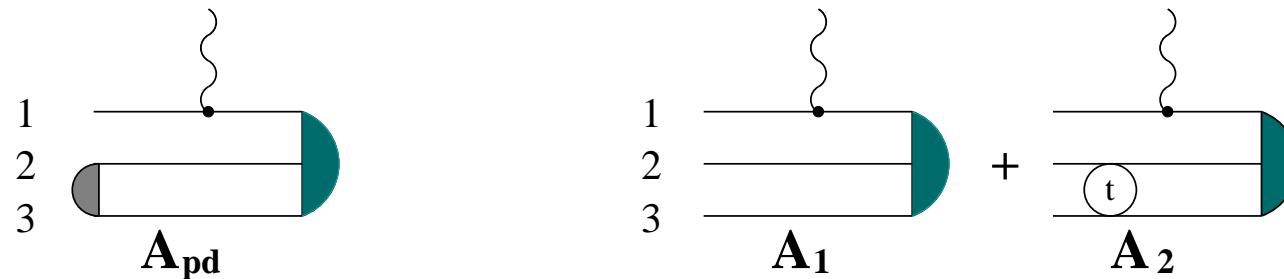
Polarized ^3He : it is easy to draw the cartoon...



- S spatially symmetric, $\approx 90\%$ of spin-averaged WF, “polarized neutron”
- D generated by tensor component of NN force, $\approx 8.5\%$
- S' mixed symmetry, (spin-isospin)-space correlations, $\approx 1.5\%$
- manifest themselves differently with changing p_{miss} in $(e, e' \{p/d/n\})$

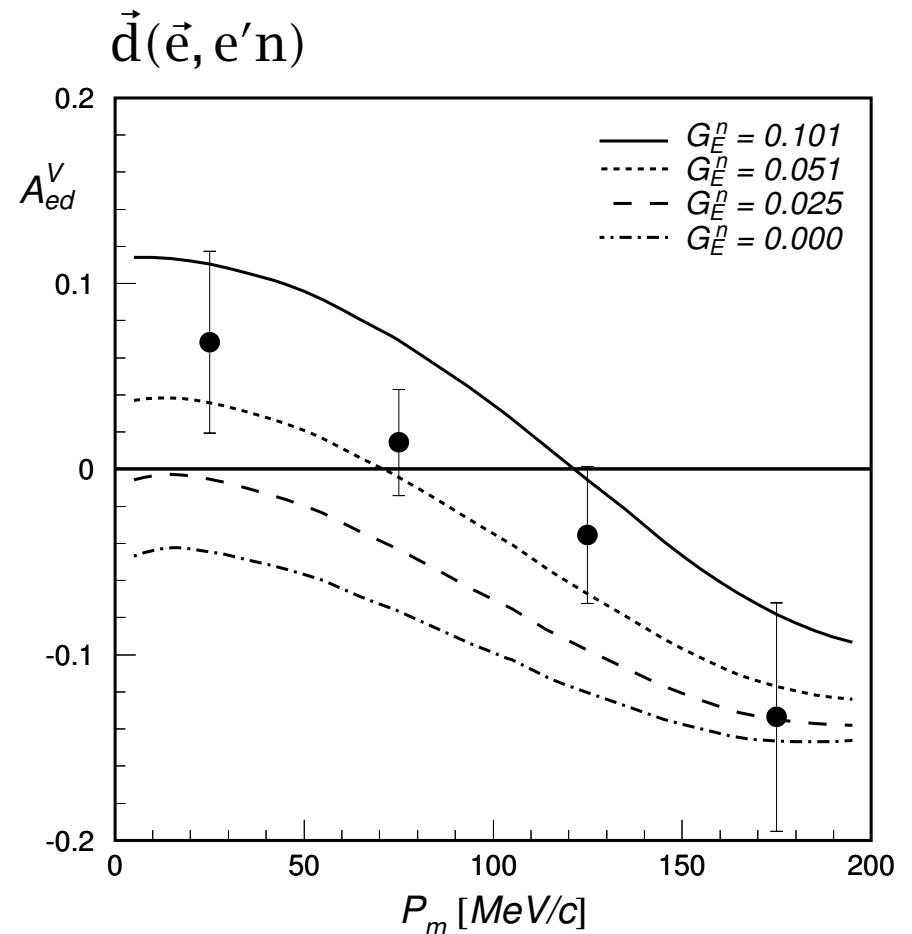
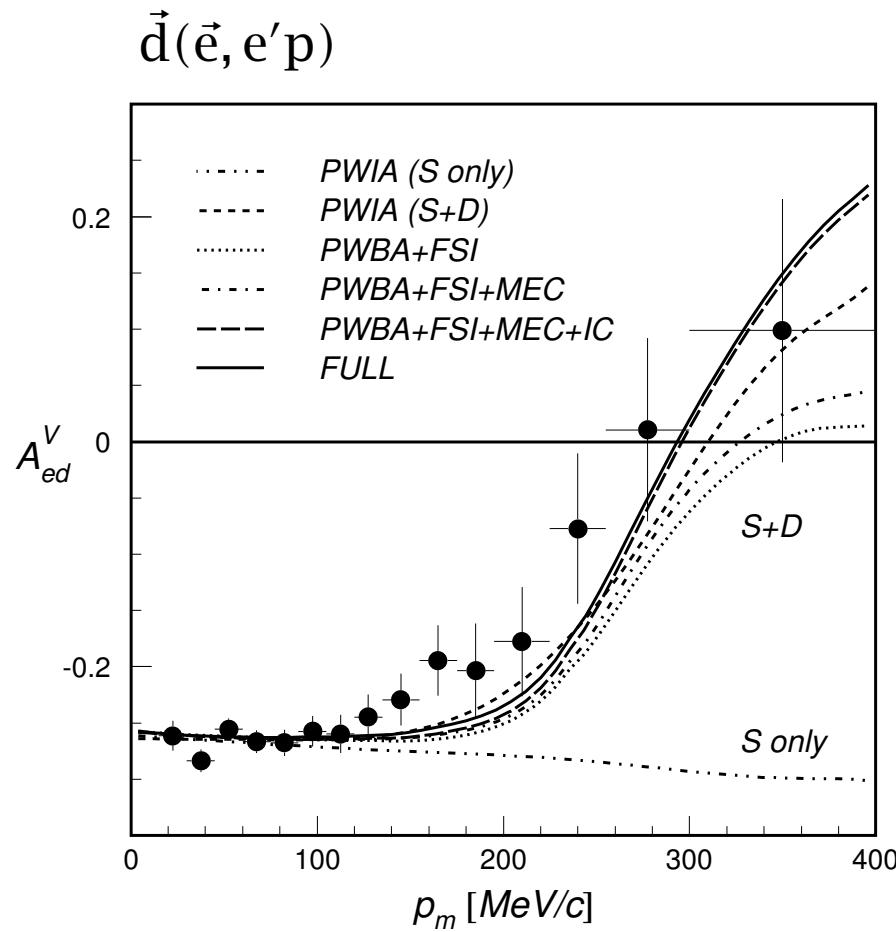
...supported e.g. by data on ${}^3\vec{\text{He}}(\vec{e}, e' p){}^2\text{H}/pn$...

- QE ($Q^2 = 0.31$, $\omega = 135$, $q = 570$)
- 3NF, MEC negligible, FSI small in 2bbu, large in 3bbu



- ▷ **2bbu**
 $A_{\text{PWIA}} \approx A_{\text{PWIA+FSI}}$
 \parallel kinematics + small p_d
 \Rightarrow polarized p target, $P_p \approx -\frac{1}{3}P_{\text{He}}$
- ▷ **3bbu**
 $A_{\text{PWIA}} \approx 0$ ($p \uparrow p \downarrow$)
 $A_{\text{PWIA+FSI}}$ large & negative
not a polarized p target

...and which has a nice analogue in the deuteron...



$$\sigma = \sigma_0 \left(1 + h P_1^d A_{ed}^V \right)$$

$$P_z^p = \sqrt{\frac{2}{3}} \left(P_S - \frac{1}{2} P_D \right) P_1^d$$

Passchier++ PRL **82** (1999) 4988

Passchier++ PRL **88** (2002) 102302

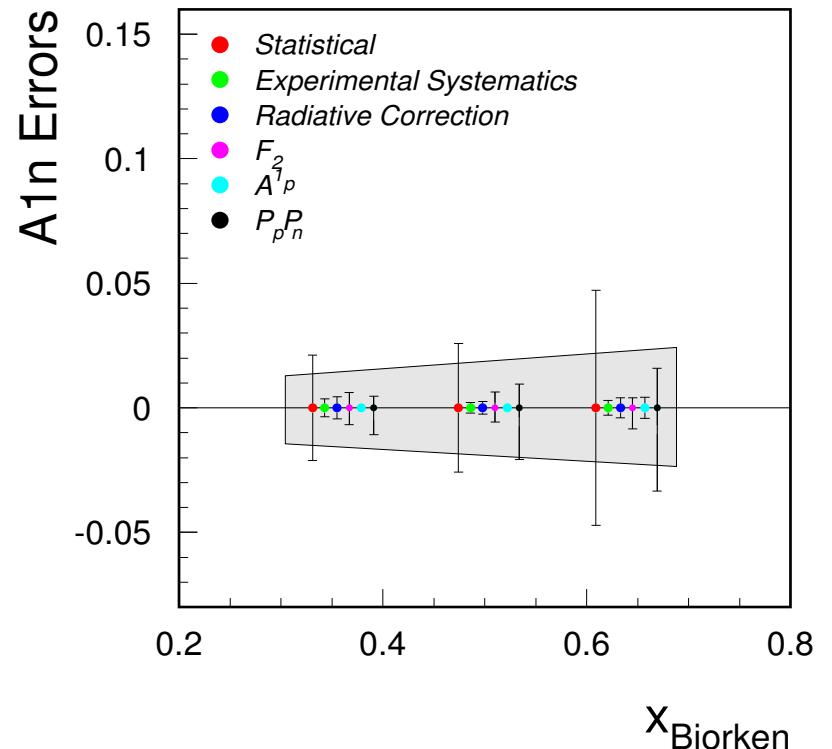
...but the true ground state of ${}^3\text{He}$ is like lace

Channel number	L	S	l_α	L_α	P	K	Probability (%)
1	0	0.5	0	0	A	1	87.44
2	0	0.5	0	0	M	2	0.74
3	0	0.5	1	1	M	1	0.74
4	0	0.5	2	2	A	1	1.20
5	0	0.5	2	2	M	2	0.06
6	1	0.5	1	1	M	1	0.01
7	1	0.5	2	2	A	1	0.01
8	1	0.5	2	2	M	2	0.01
9	1	1.5	1	1	M	1	0.01
10	1	1.5	2	2	M	2	0.01
11	2	1.5	0	2	M	2	1.08
12	2	1.5	1	1	M	1	2.63
13	2	1.5	1	3	M	1	1.05
14	2	1.5	2	0	M	2	3.06
15	2	1.5	2	2	M	2	0.18
16	2	1.5	3	1	M	1	0.37

Blankleider, Woloshyn PRC 29 (1984) 538

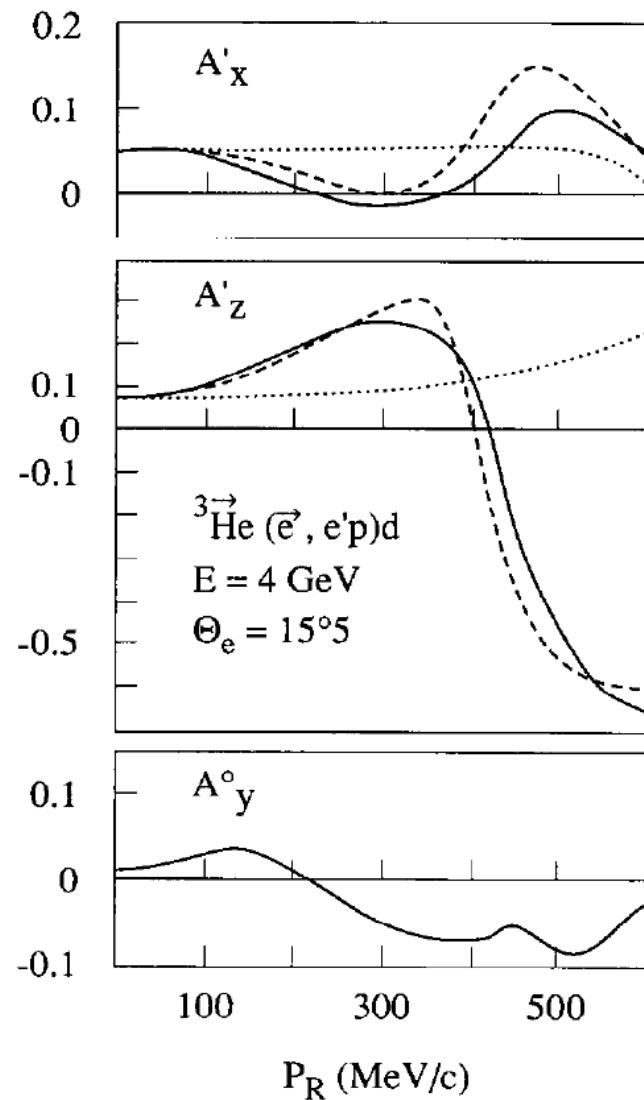
The E05-102 experiment

- Benchmark measurement of A'_x and A'_z asymmetries in ${}^3\vec{\text{He}}(\vec{e}, e'd)$, ${}^3\vec{\text{He}}(\vec{e}, e'p)$, and ${}^3\vec{\text{He}}(\vec{e}, e'n)$.
- Better understanding of ground-state spin structure of polarized ${}^3\text{He}$ —
 - S, S', D wave-function components.
 - Improve knowledge of ${}^3\text{He}$ rather than using it as an effective neutron target.
- Direct consequences for all polarized ${}^3\text{He}$ experiments.
- Data at (almost) identical Q^2 for $(\vec{e}, e'd)$, $(\vec{e}, e'p)$, and $(\vec{e}, e'n)$ simultaneously over a broad range of p_{miss} poses strong constraints on state-of-the-art calculations.

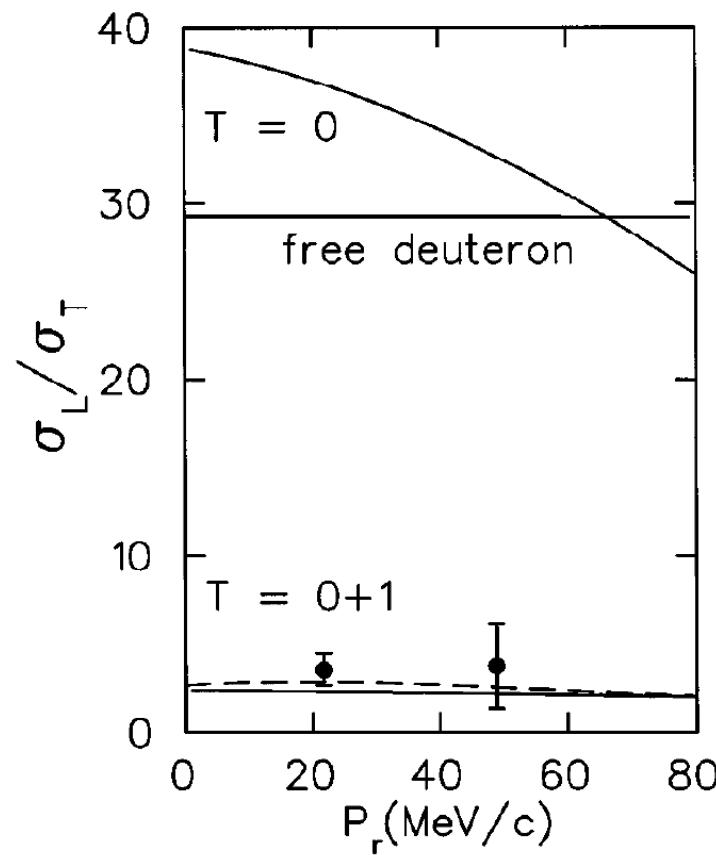


details on setup and HRS calibration → Ge Jin
details on BigBite calibrations → Miha Mihovilović

What is so special about ${}^3\text{He}(\text{e}, \text{e}'\text{d})$ and ${}^3\vec{\text{He}}(\vec{\text{e}}, \text{e}'\text{d})$?



in $(\text{e}, \text{e}'\text{p})$ the D/S effects
seen only at high p_{miss}



unique isoscalar-isovector
interference in $(\text{e}, \text{e}'\text{d})$

Laget PLB **276** (1992) 398
Tripp++ PRL **76** (1996) 885

Ingredients of calculations

Bochum/Krakow:

- Faddeev calculation
- AV18 NN potential
- Urbana IX 3NF
- FSI
- “standard” MEC
- charge-density MEC
(sensitive to high-momentum components)
- Coulomb interactions

Hannover:

- Faddeev calculation
- CD Bonn NN potential
- inclusion of Δ mimics 3NF
- FSI
- “standard” MEC
- relativistic charge corrections
- Coulomb interactions

Recently also obtained results of the **Pisa** group:

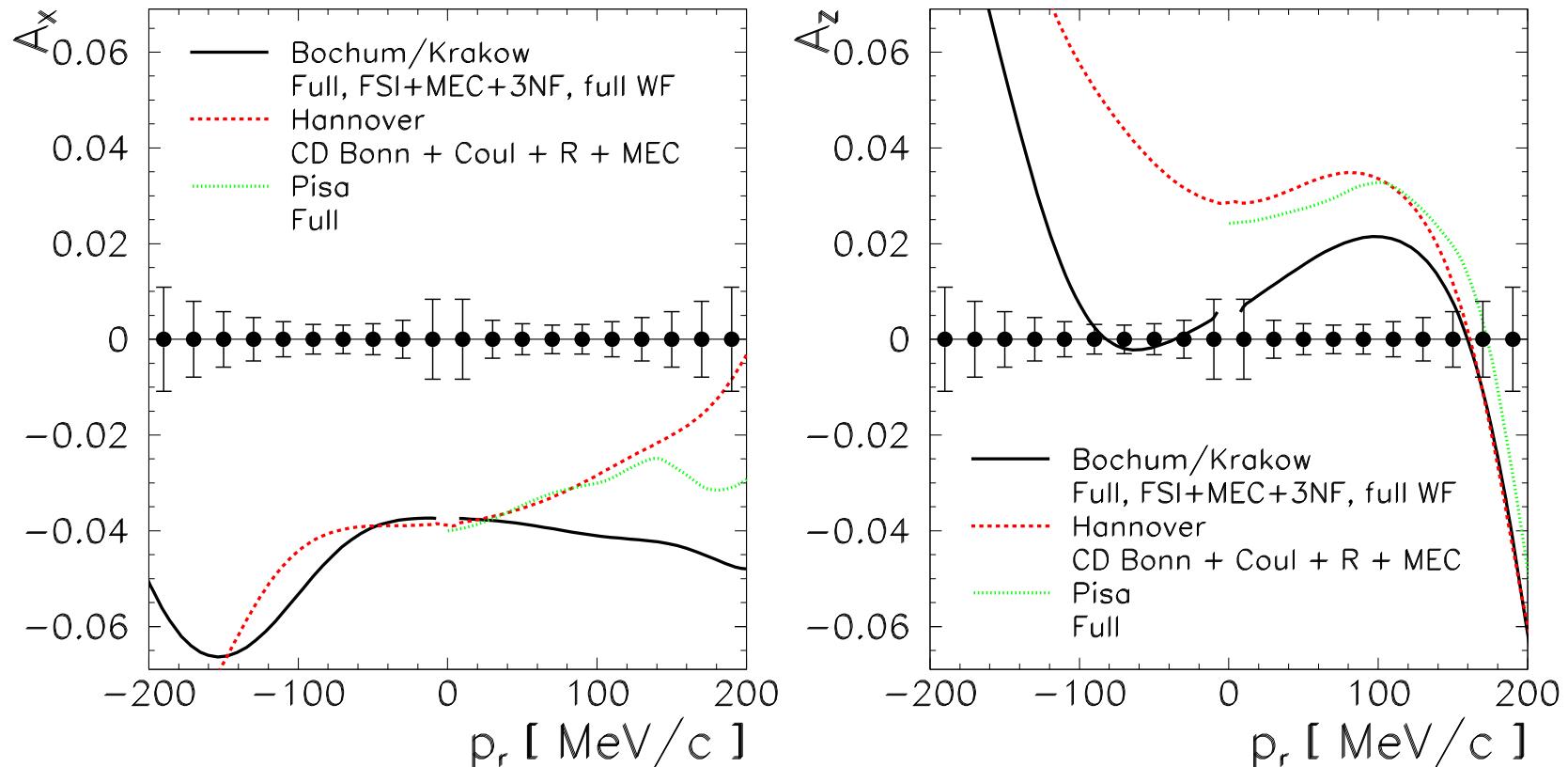
- AV18 + Urbana IX
- full FSI (variational PHH expansion) and MEC
- not Faddeev but of completely equivalent accuracy

Comparison of full calculations

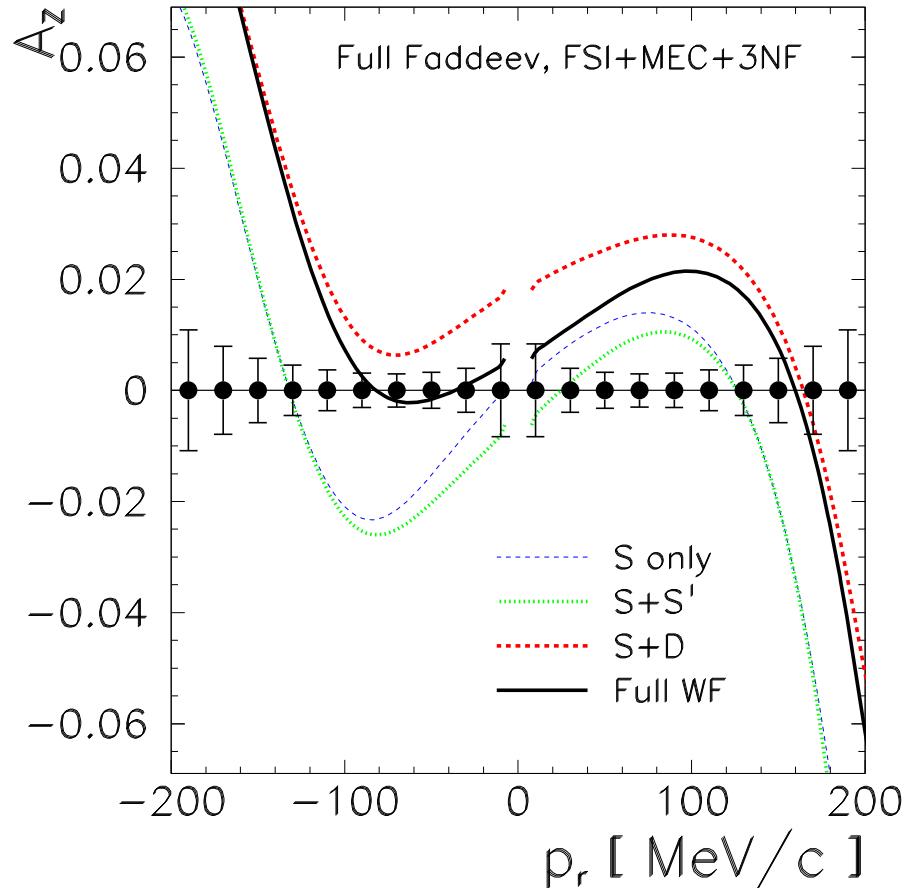
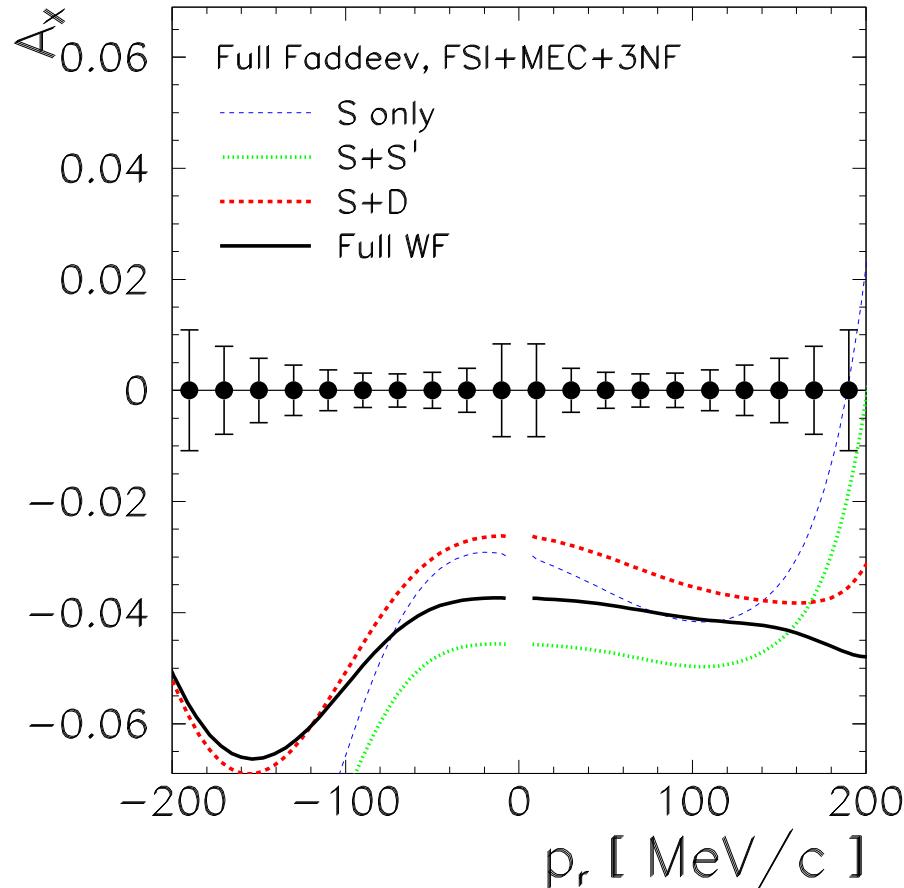
${}^3\vec{\text{He}}(\vec{e}, e'd)$

$$\frac{d\sigma(h, \vec{S})}{d\Omega_e dE_e d\Omega_d dp_d} = \frac{d\sigma_0}{\dots} \left[1 + \vec{S} \cdot \vec{A}^0 + h(\mathcal{A}_e + \vec{S} \cdot \vec{A}) \right]$$

$$A_{x,z} = \frac{[d\sigma_{++} + d\sigma_{--}] - [d\sigma_{+-} + d\sigma_{-+}]}{[d\sigma_{++} + d\sigma_{--}] + [d\sigma_{+-} + d\sigma_{-+}]}$$

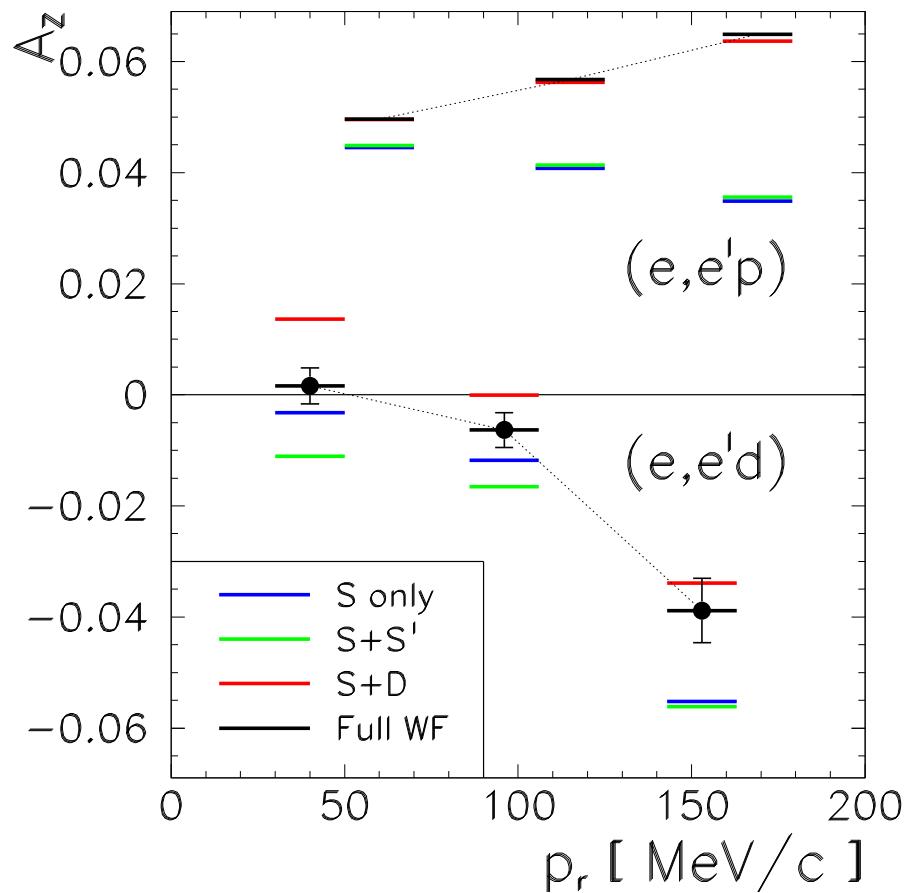
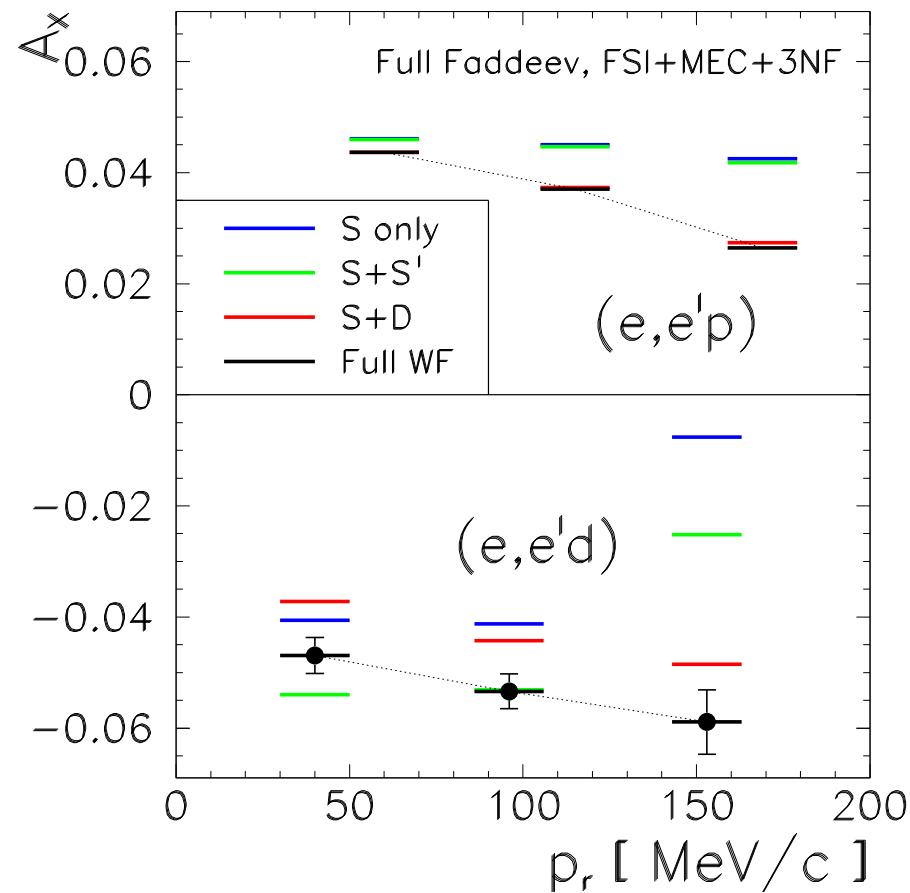


Bochum/Krakow wave-function truncation

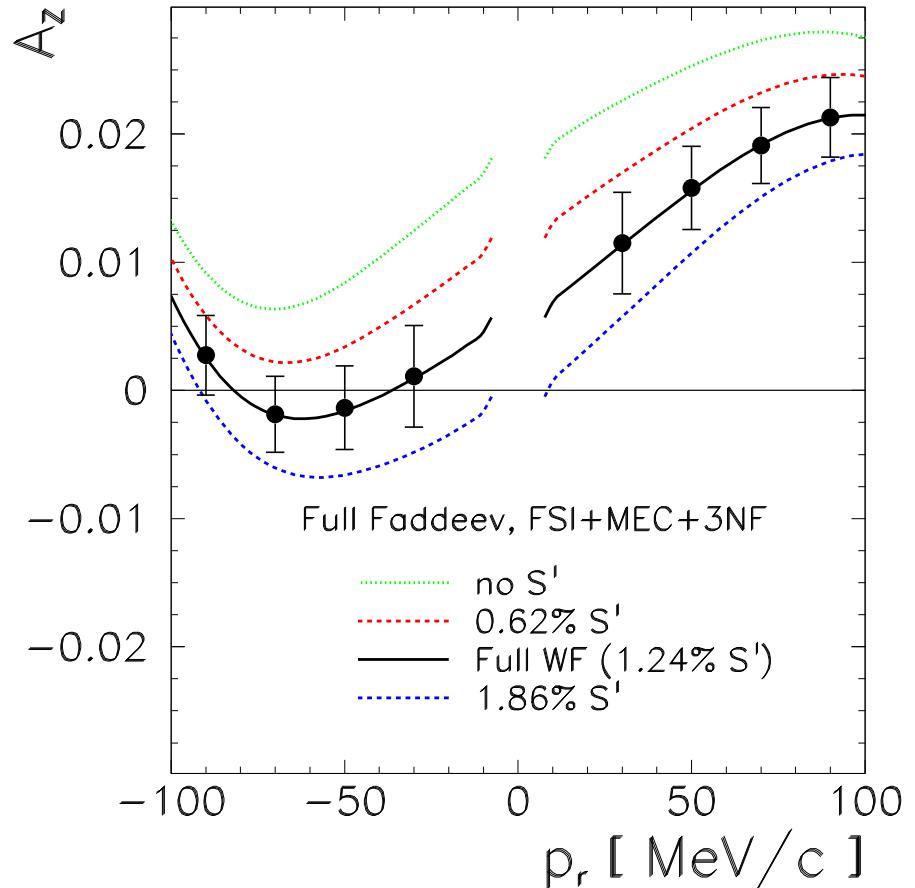
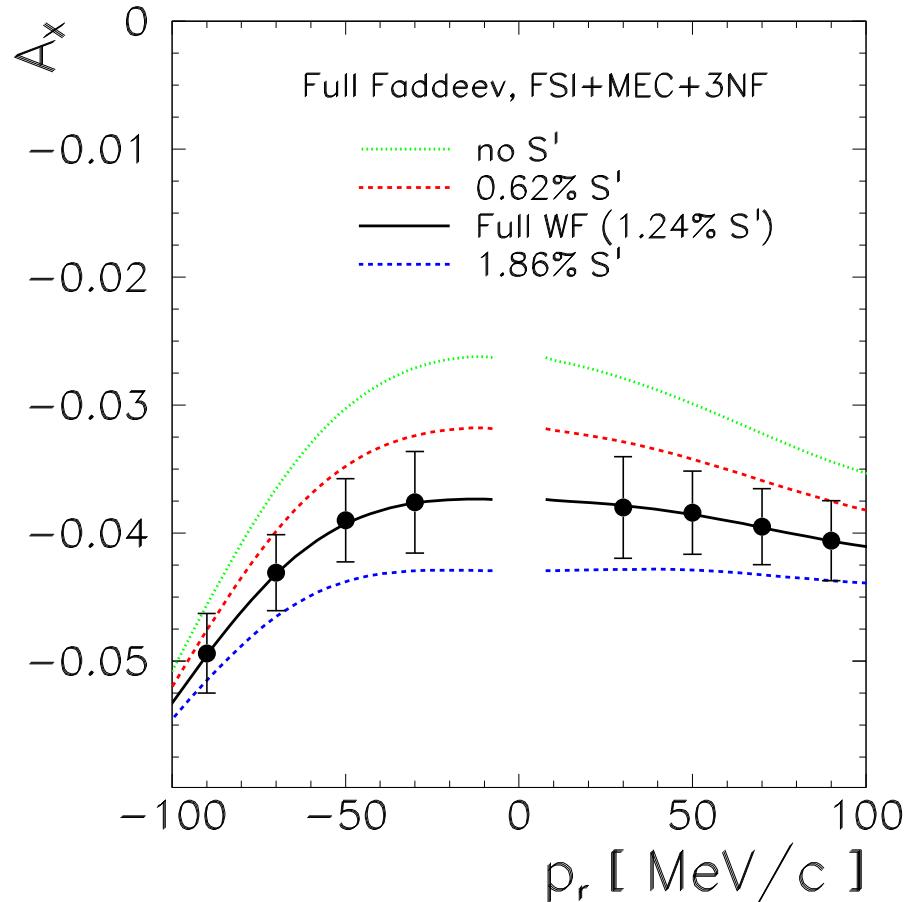


- non-trivial game to play (changes in the bound state imply changes in the scattering state as well — consistency issues)

${}^3\vec{\text{He}}(\vec{e}, e'd)$ vs. ${}^3\vec{\text{He}}(\vec{e}, e'p)$



Bochum/Krakow sensitivity to S'



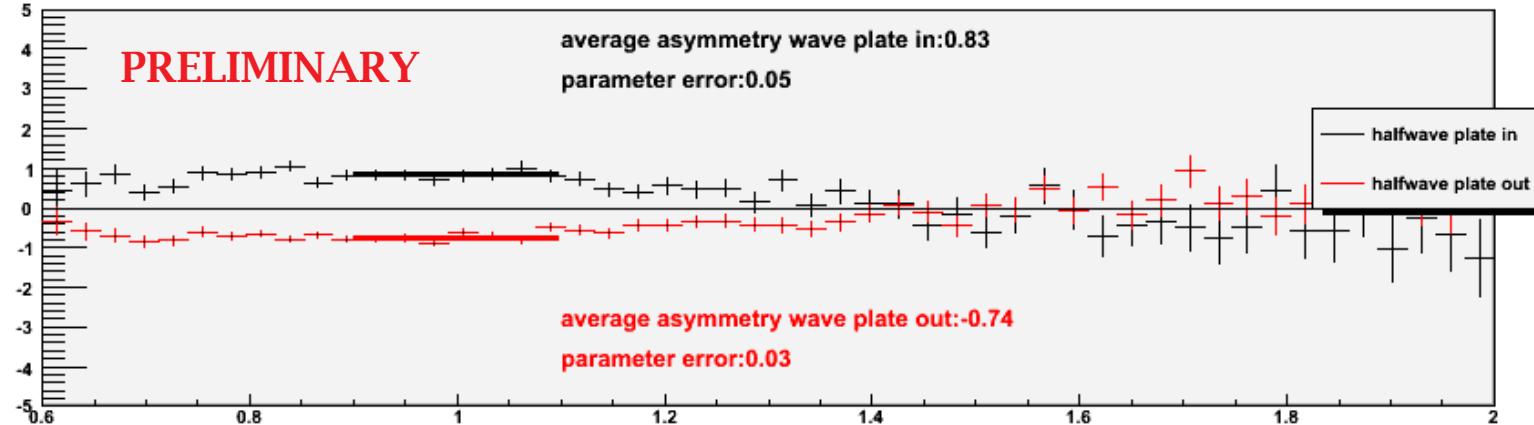
${}^3\vec{\text{He}}(\vec{e}, e')$ inclusive asymmetries, $Q^2 \approx 0.35$

($\rightarrow G_M^n$)

approx 3 days of running

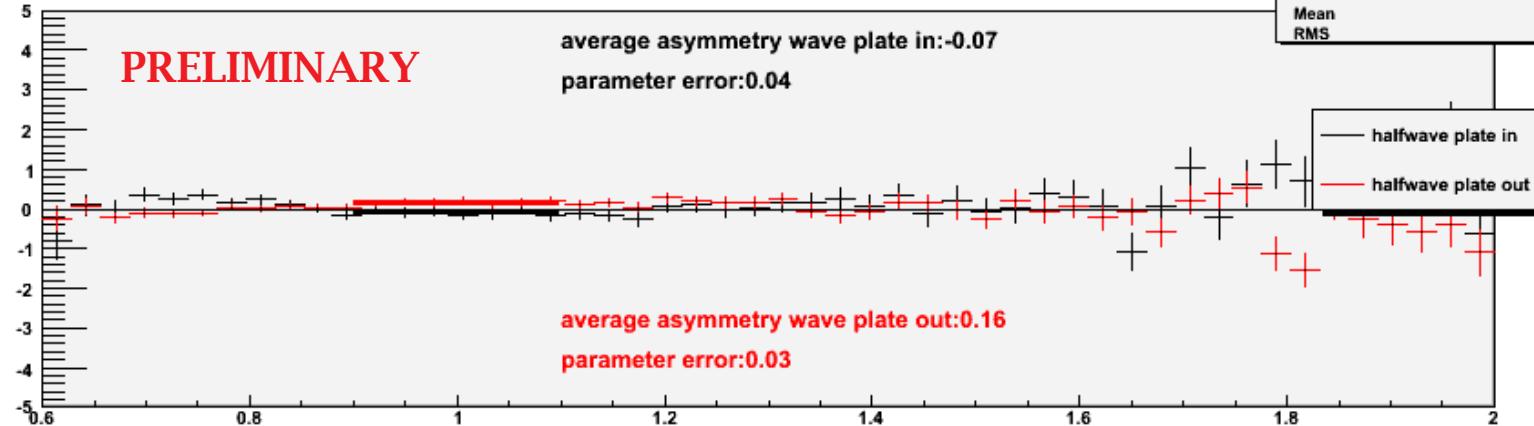
Measured beam-target asymmetry

TRANSVERSE wrt beam

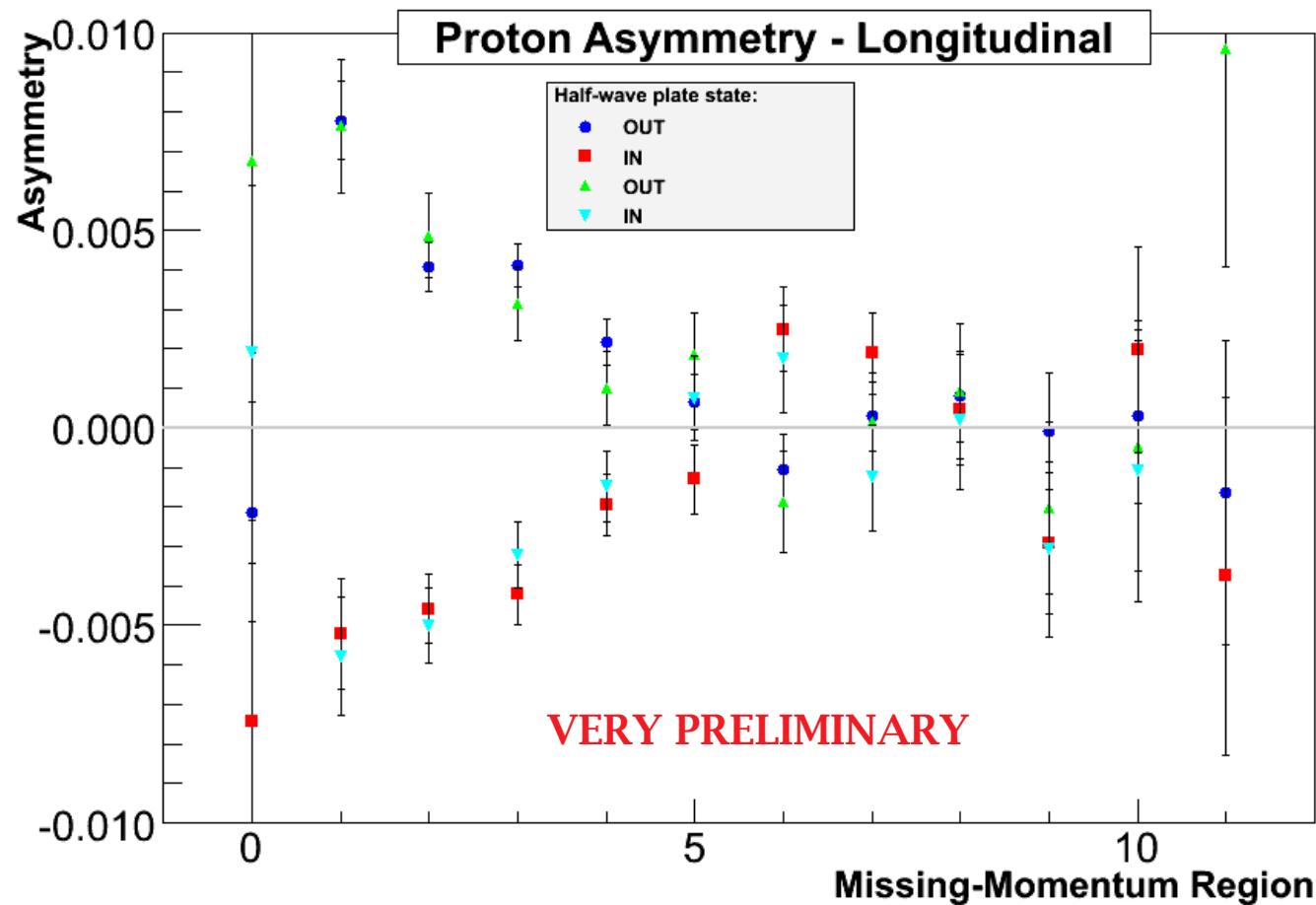


Measured beam-target asymmetry

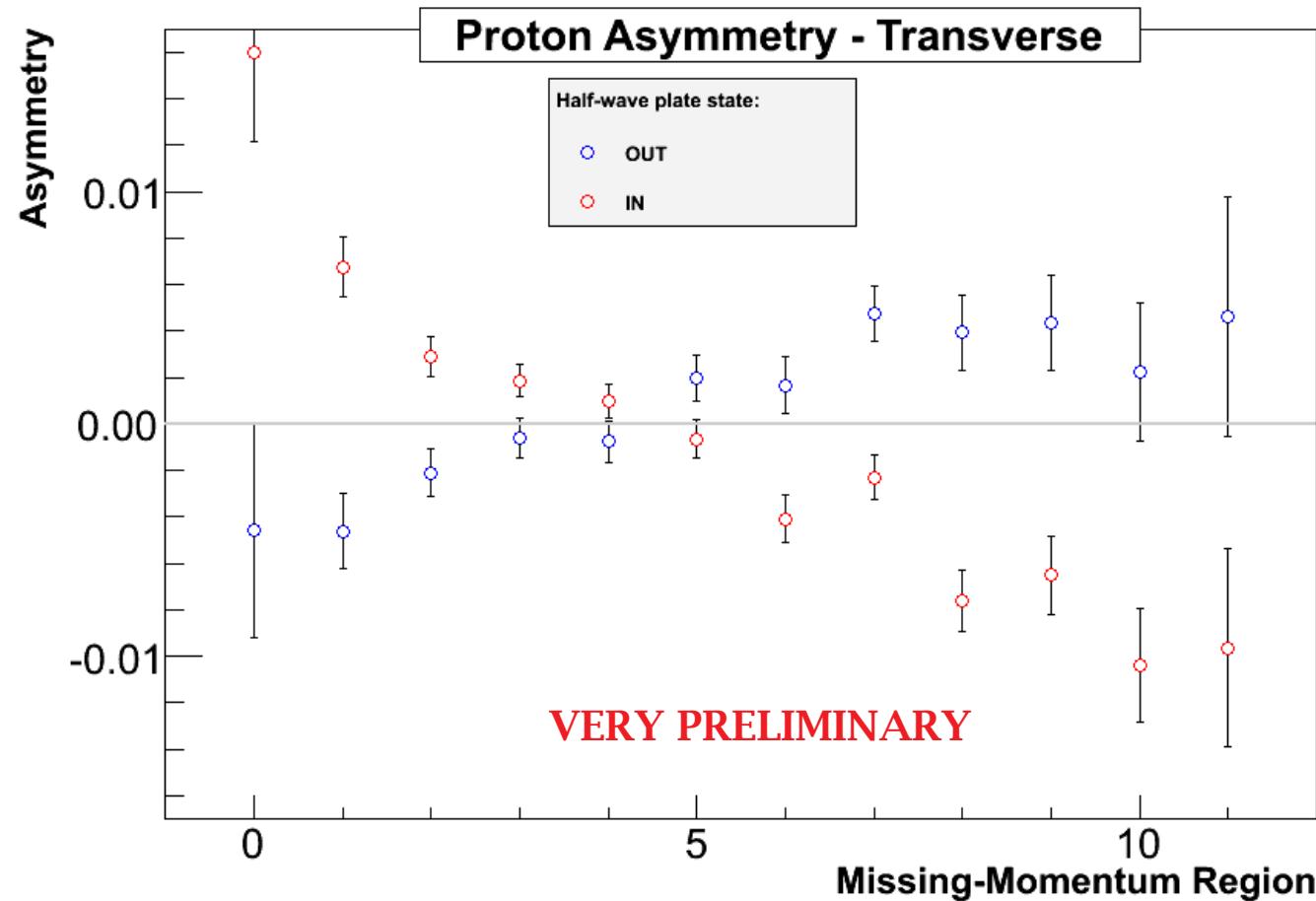
LONGITUDINAL wrt beam



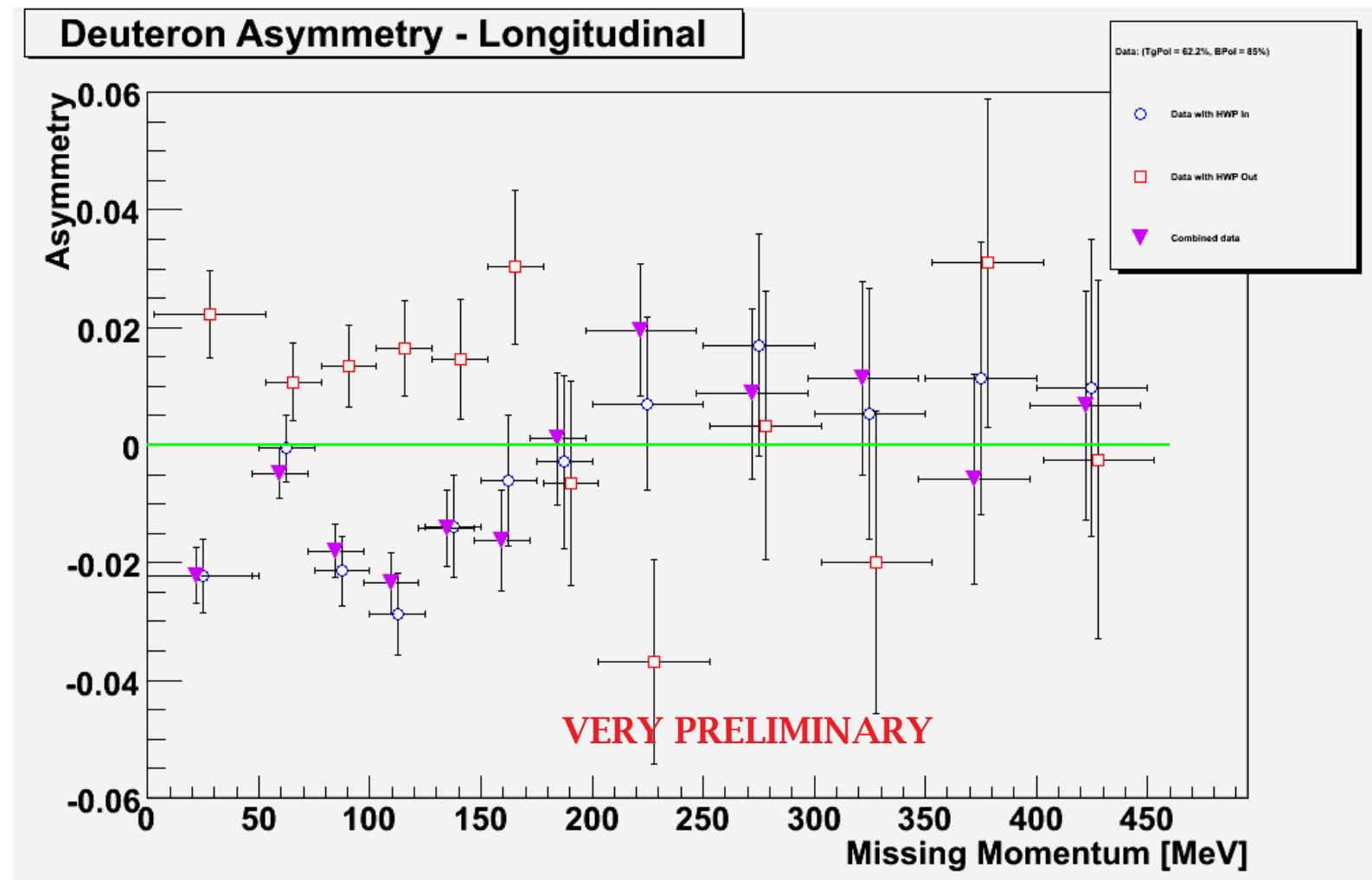
Asymmetries in ${}^3\vec{\text{He}}(\vec{e}, e' p)$



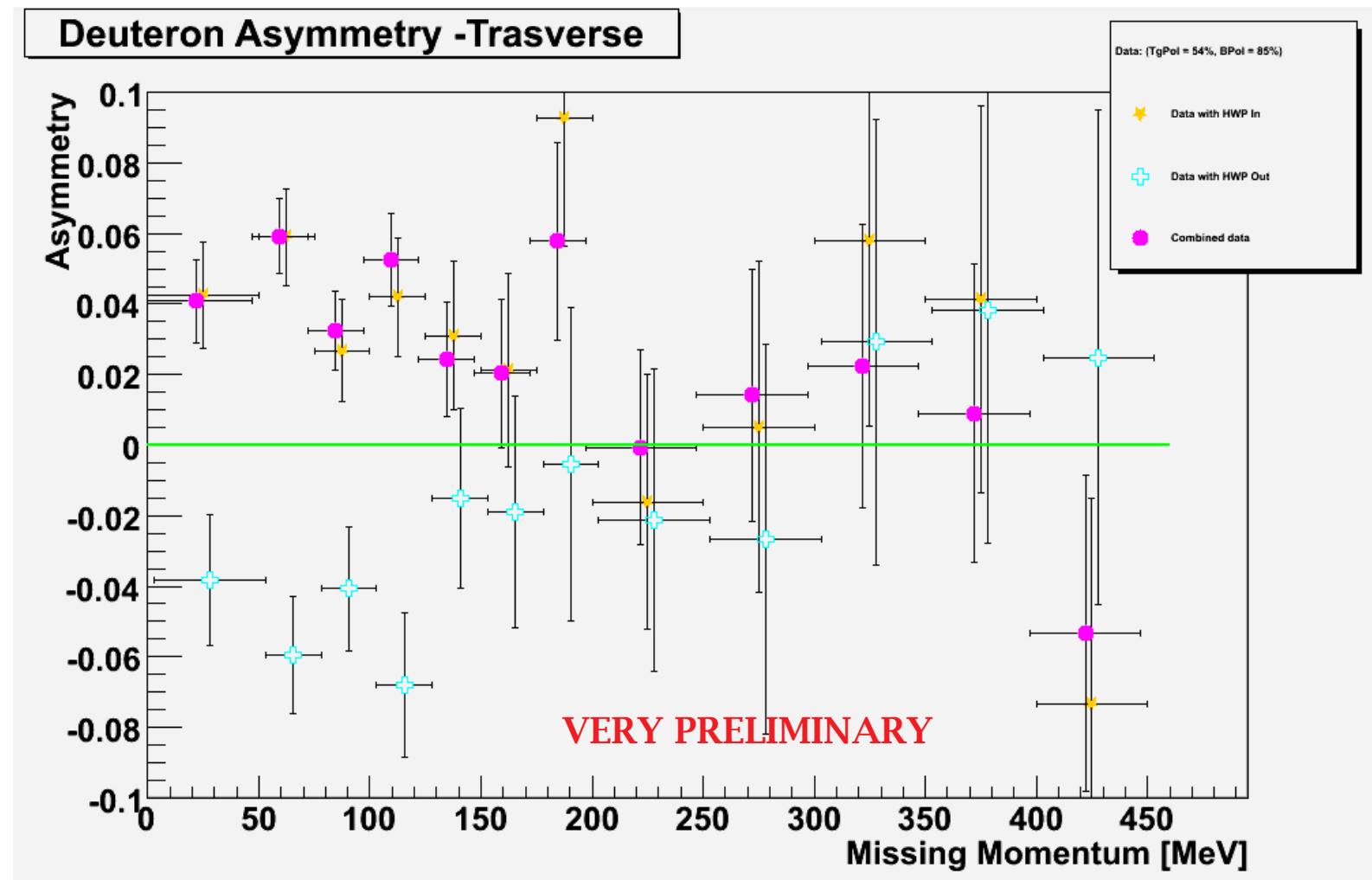
Asymmetries in ${}^3\vec{\text{He}}(\vec{e}, e' p)$



Asymmetries in ${}^3\vec{\text{He}}(\vec{e}, e'd)$



Asymmetries in ${}^3\vec{\text{He}}(\vec{e}, e'd)$



Outlook: triple-polarized ${}^3\text{He}(\vec{e}, e' \vec{p})$

MAMI/A1

- spin-dependent momentum distributions of $\vec{p}\vec{d}$ clusters in polarized ${}^3\text{He}$

$$N_\mu = \langle \Psi_{pd}^{(-)} M_d m | \hat{j}_\mu(\vec{q}) | \Psi M \rangle$$

$$\gamma \left(M = \frac{1}{2}, M_d = 0, m = +\frac{1}{2} \right) \propto \left| N_{-1}^{\text{spin PWIA}} \left(\frac{1}{2}, 0, -\frac{1}{2} \right) \right|^2$$

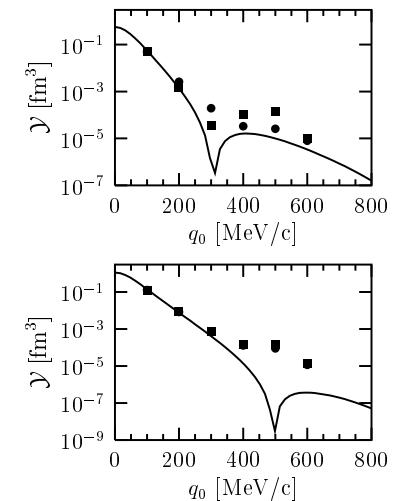
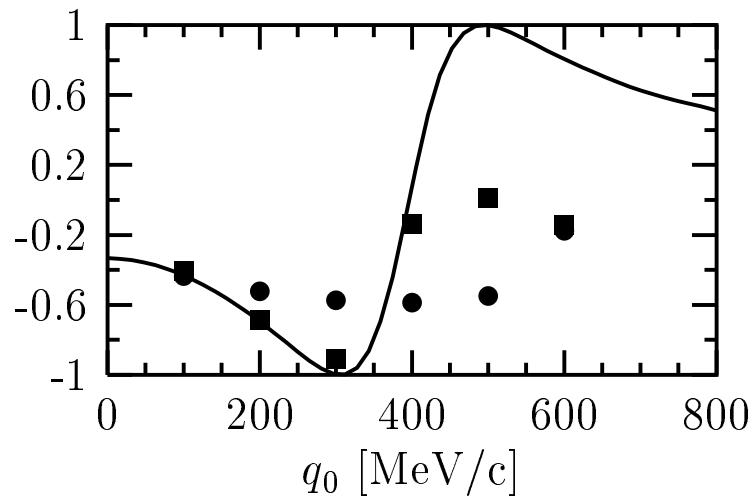
$$\gamma \left(M = \frac{1}{2}, M_d = 1, m = -\frac{1}{2} \right) \propto \left| N_{+1}^{\text{spin PWIA}} \left(\frac{1}{2}, 1, +\frac{1}{2} \right) \right|^2$$

$$A = \frac{\gamma(1/2, 0, 1/2) - \gamma(1/2, 1, -1/2)}{\gamma(1/2, 0, 1/2) + \gamma(1/2, 1, -1/2)}$$

$$\sigma_L \propto |N_0|^2$$

$$\sigma_T \propto |N_{+1}|^2 + |N_{-1}|^2$$

$$\sigma_{T'} \propto |N_{+1}|^2 - |N_{-1}|^2$$



Golak++ PRC 65 (2002) 064004

Outlook: triple-polarized ${}^3\text{He}(\vec{e}, e' \vec{p})$

MAMI/A1

- PWIA: σ_L , σ_T , $\sigma_{T'}$ yield spin-dependent momentum distribution
- FSI, MEC preclude direct access except at $p_d \lesssim 2 \text{ fm}^{-1}$
- rich interplay \triangleright final-state symmetrization: large effect in C_3
 - \triangleright FSI: largest in C_2
 - \triangleright MEC: most prominent in C_1

