Know Your Target: Towards a Better Understanding of $\longrightarrow$ the ^{3}He System

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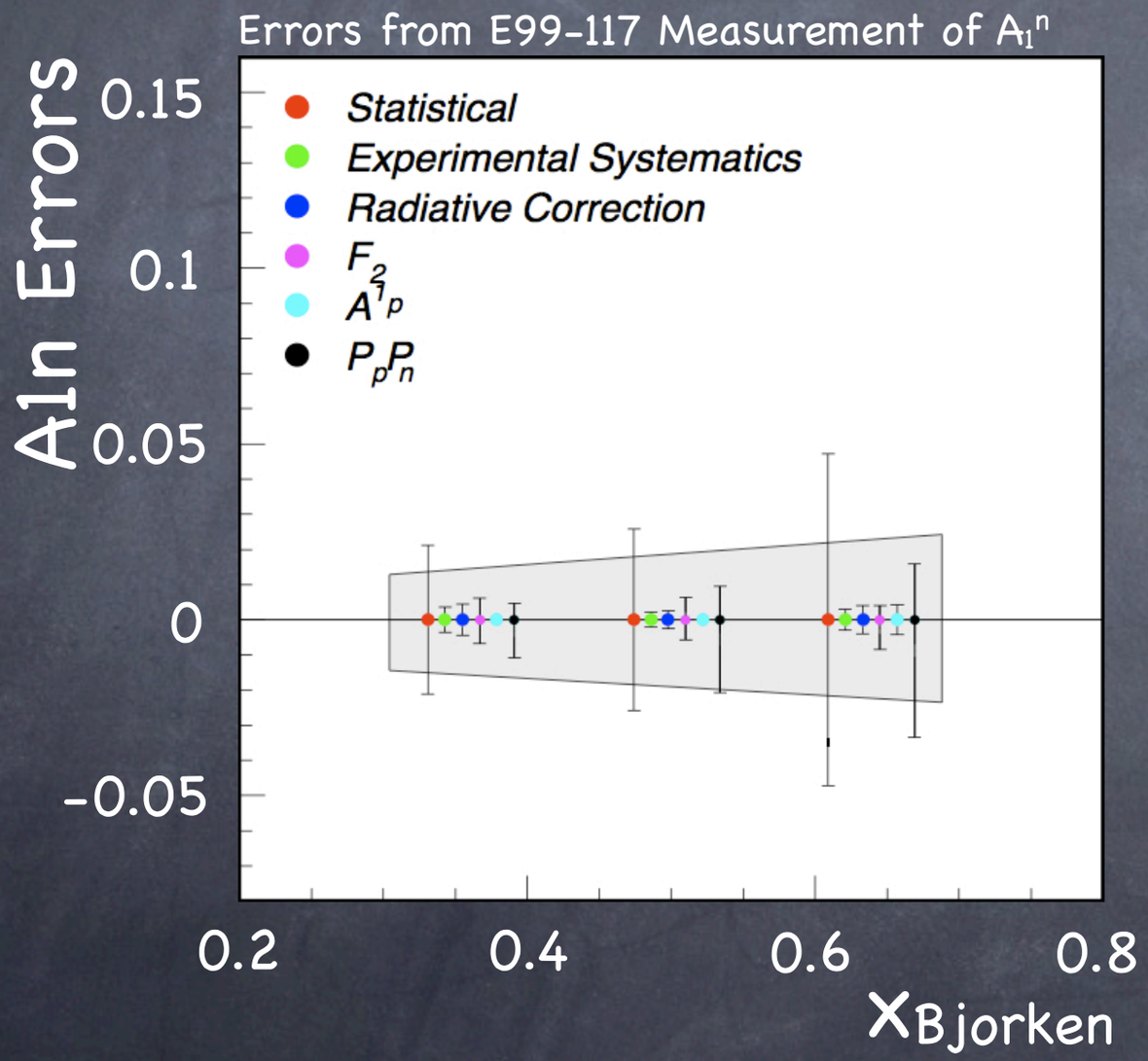
KENT STATE UNIVERSITY

Jefferson Lab

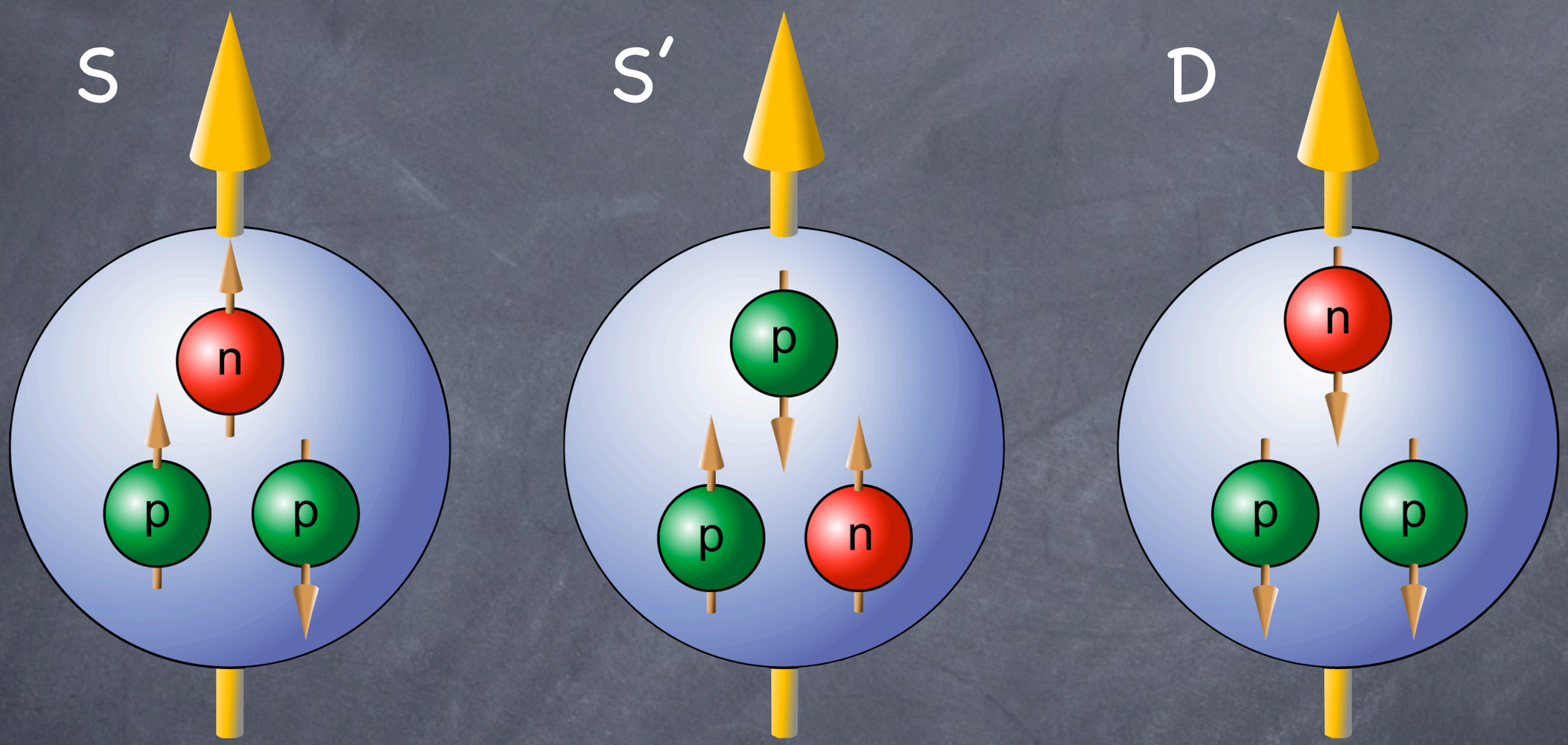
Why Study ^{3}He?

- Effective neutron target



- After Statistical, the highest error is in the proton and neutron polarizations
- Relate to components of ^{3}He wave function

Ground State



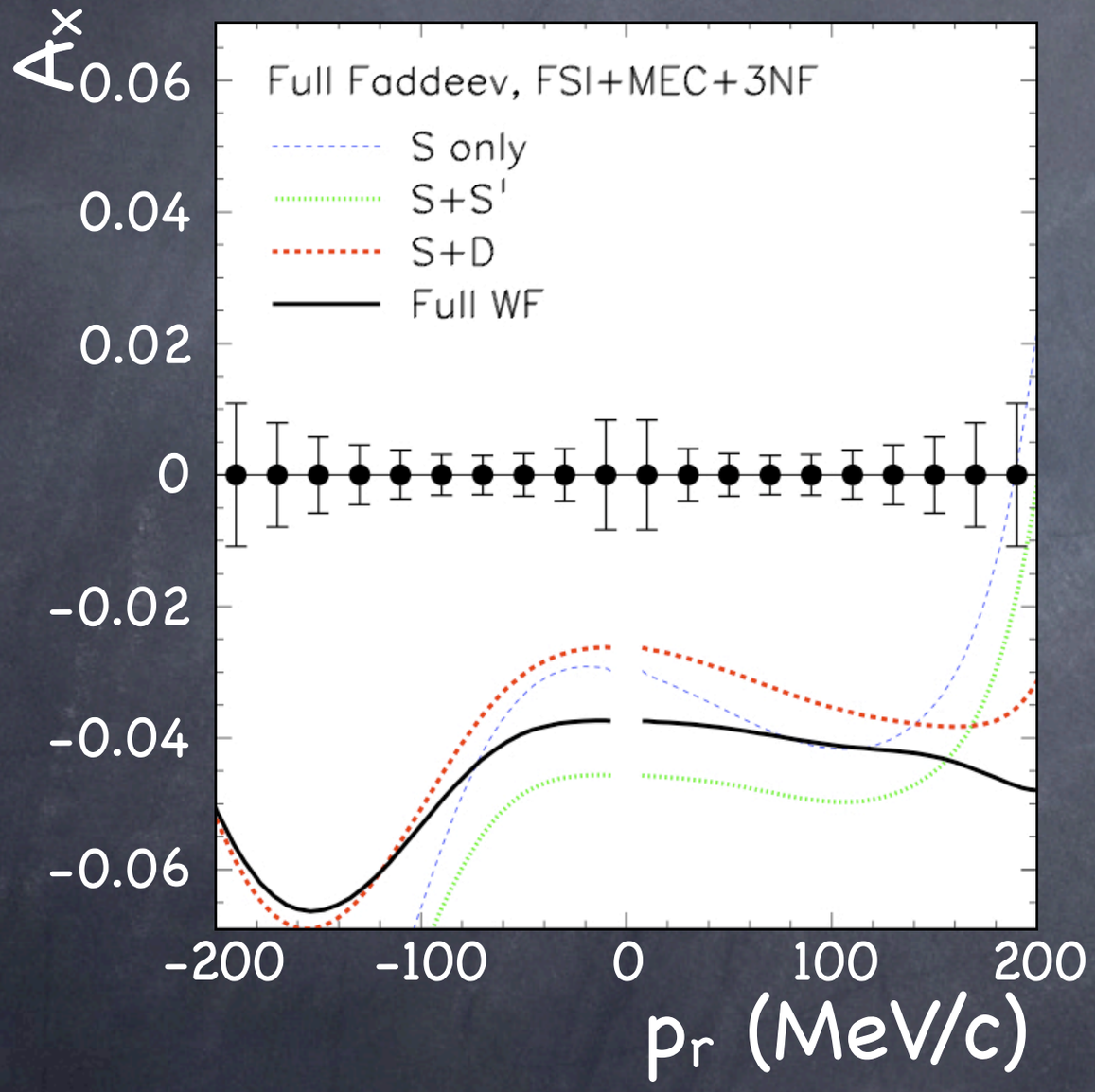
90% Spatially Symmetric

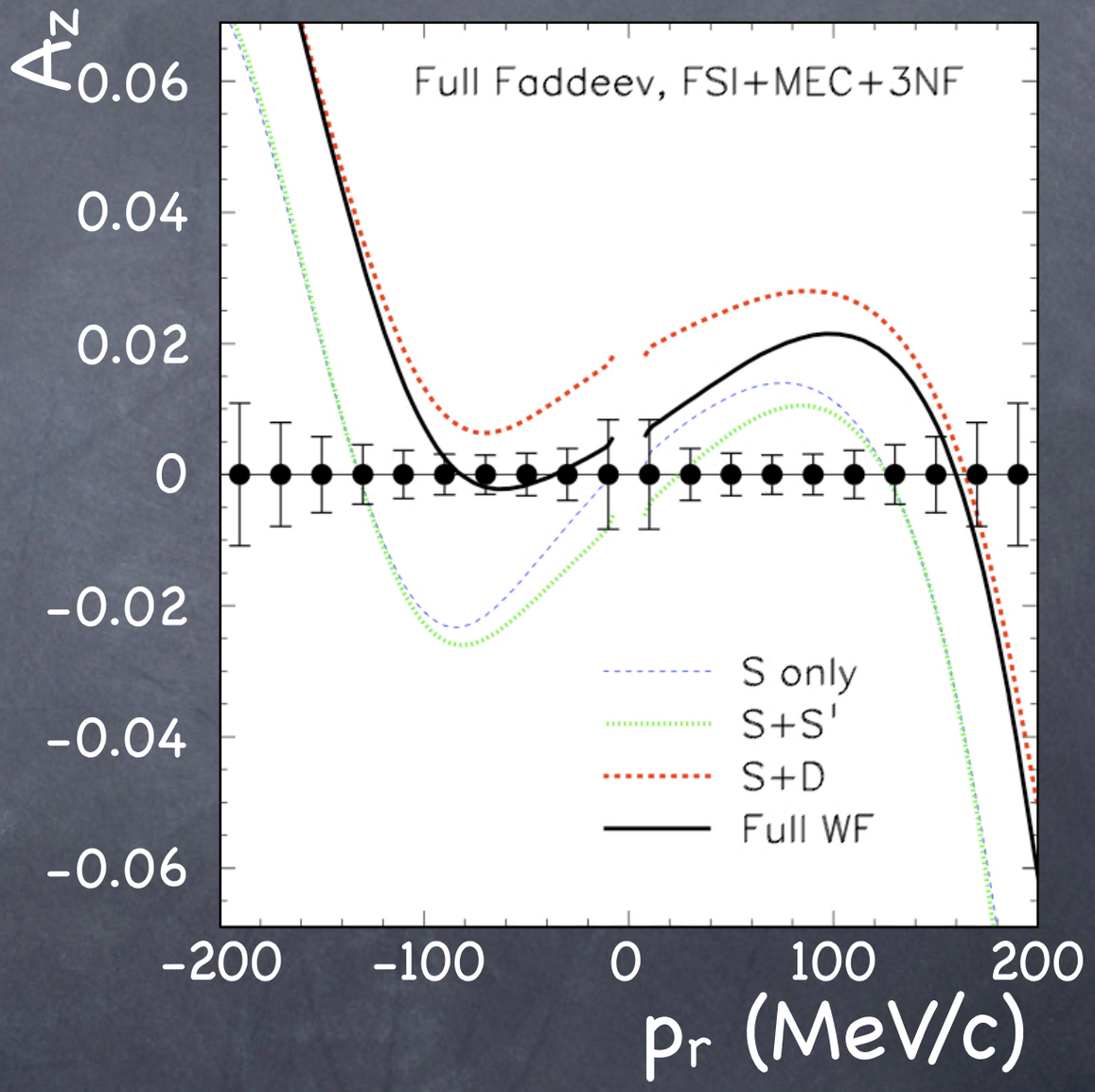
~1.5% Mixed Symmetry Configuration

~8.5%

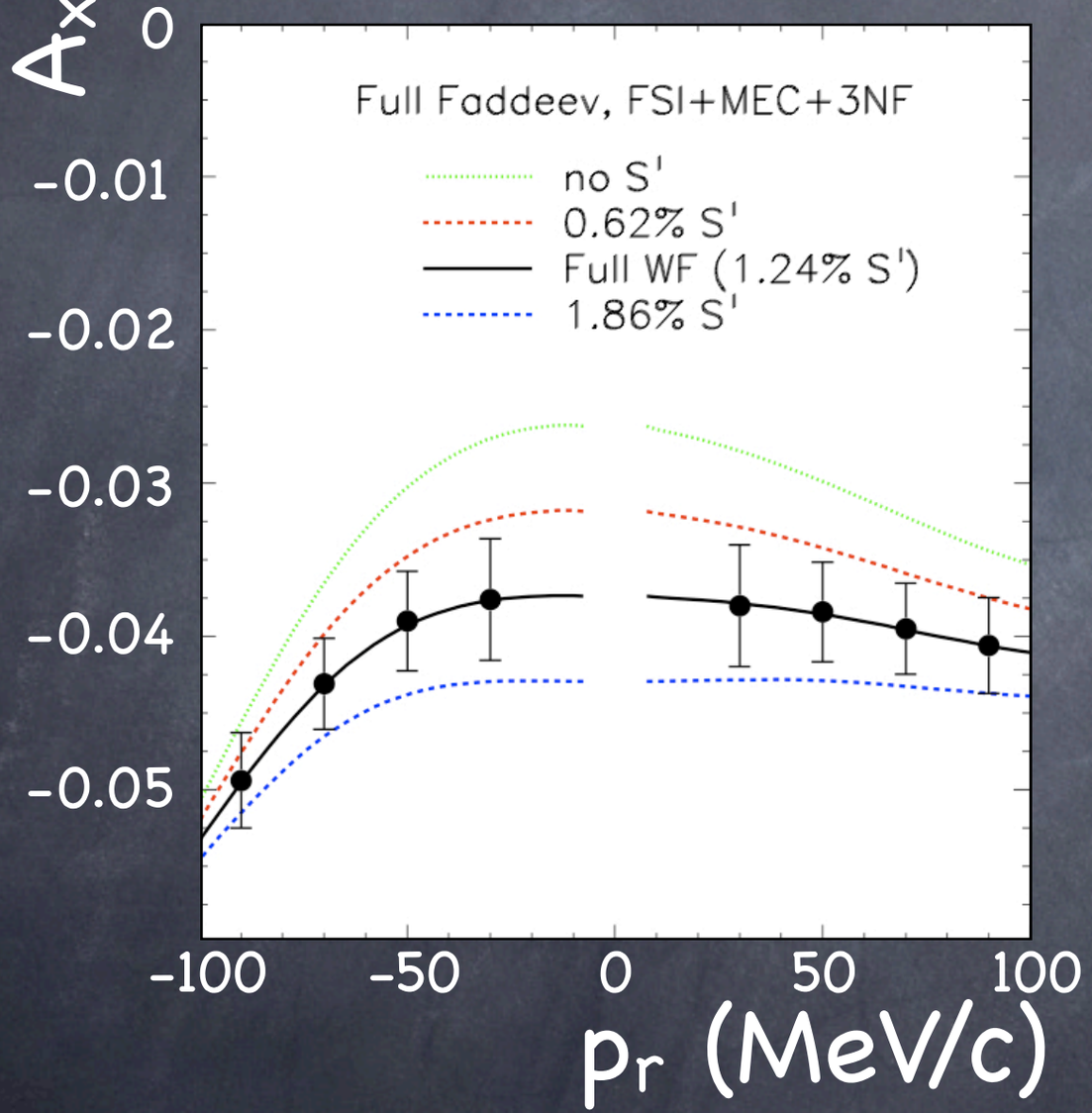
- Not Observables

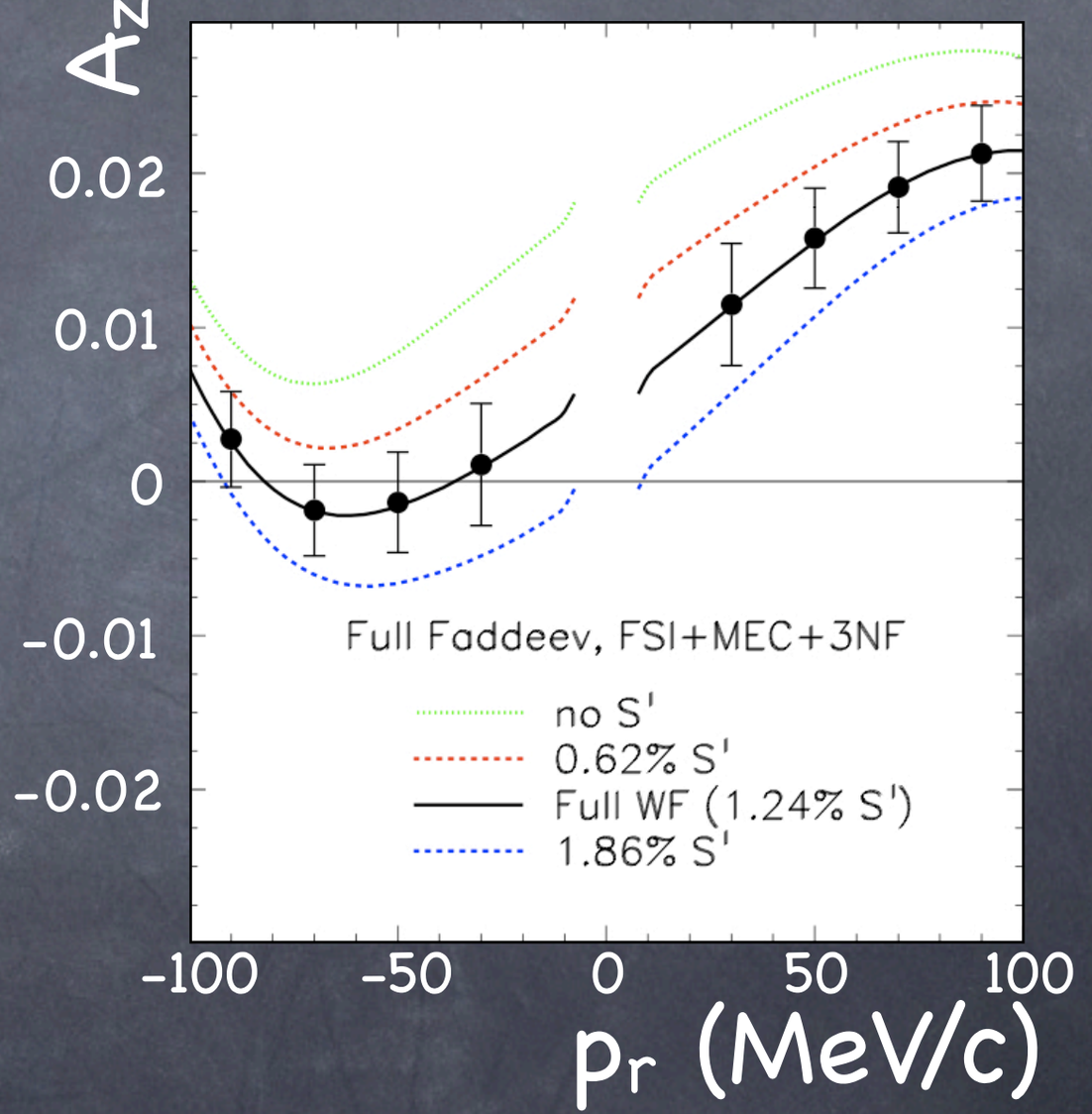
Full Faddeev Calculations Sensitivity to States





Full Faddeev Calculations Sensitivity to S′



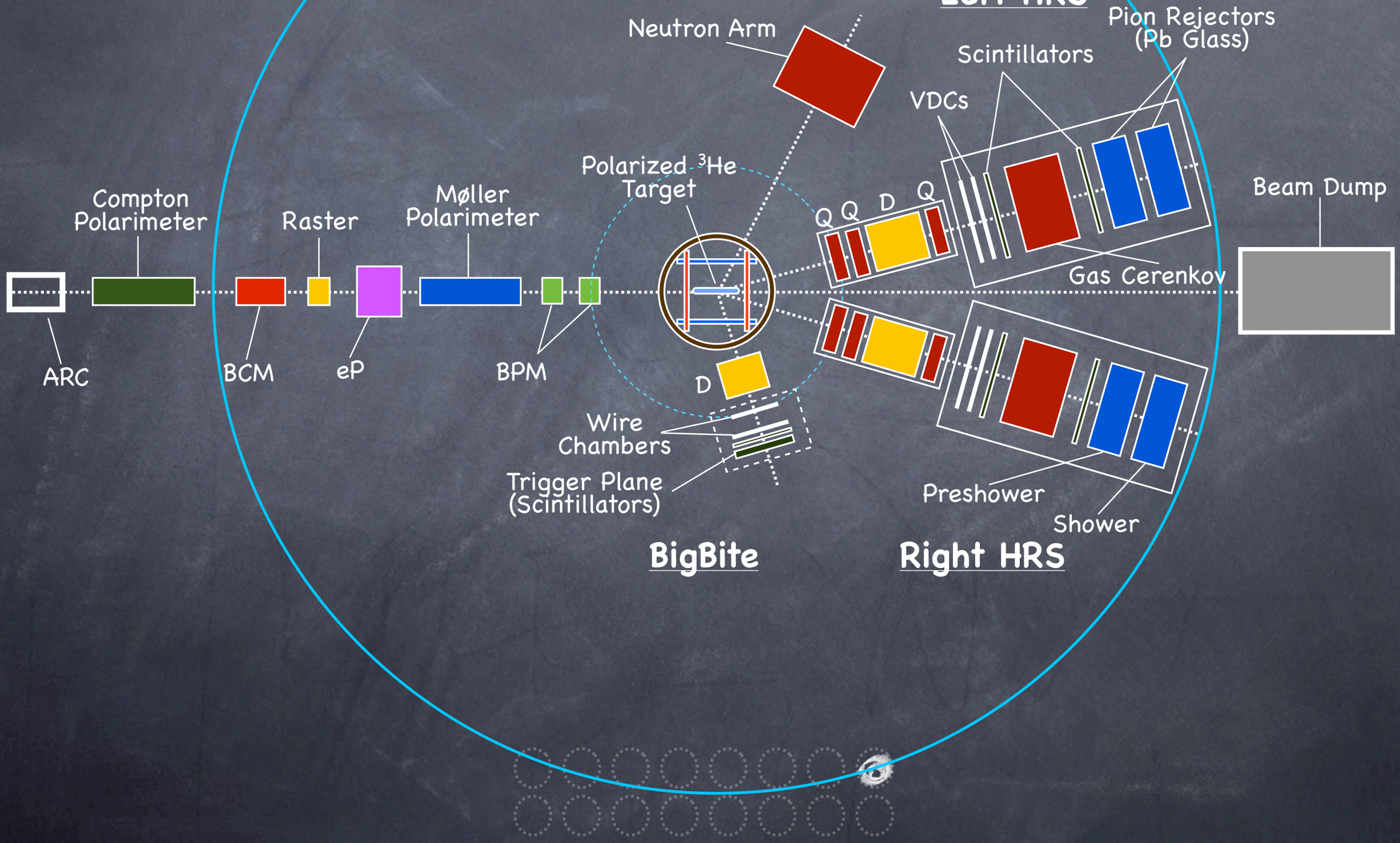


Jefferson Lab

Experiment Set-Up

- Beam Energy 2.4 GeV
- Electron Scattering Angle of 15°
- Momentum Transfer of 620 MeV/c
- BigBite will get perpendicular kinematics up to ~200MeV/c
- Beam Helicity fast-flipped (30 Hz)

Hall A


Left HRS
Neutron Arm
Pion Rejectors
(Pb Glass)
Scintillators
VDCs
Polarized ^{3}He
Target
Q Q D Q
Beam Dump
Compton
Polarimeter
Raster
Møller
Polarimeter
Gas Cerenkov
ARC
BCM
eP
BPM
D
Wire
Chambers
Trigger Plane
(Scintillators)
Preshower
Shower
BigBite
Right HRS


Incident Polarized
Electron
Scattered
Electron
15°
h
γ*
q
72.8°
n
p
p
A_x
A_z
n
p

LHRS

- Detects Quasi-Elastically Scattered Electrons from ^{3}He(e,e'd)p
- Angular Resolution
  - ~0.6mr in Non-Dispersive Plane
  - ~0.2mr in Dispersive Plane
- Momentum Acceptance
  - ±4.5%
- Angular Acceptance
  - ±60 mr in Dispersive Plane
  - ±22 mr in Non-Dispersive Plane

RHRS

- Moniters $P_e P_t$ and Luminosity

BigBite

- Detects Deuterons from ^{3}He(e,e'd)p
- Angle set at 72.8°
- Solid Angle of 96 msr
- Momentum Acceptance
  - 200-900 MeV

Formalism of $^3\overrightarrow{He}(\vec{e},e'd)p$

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

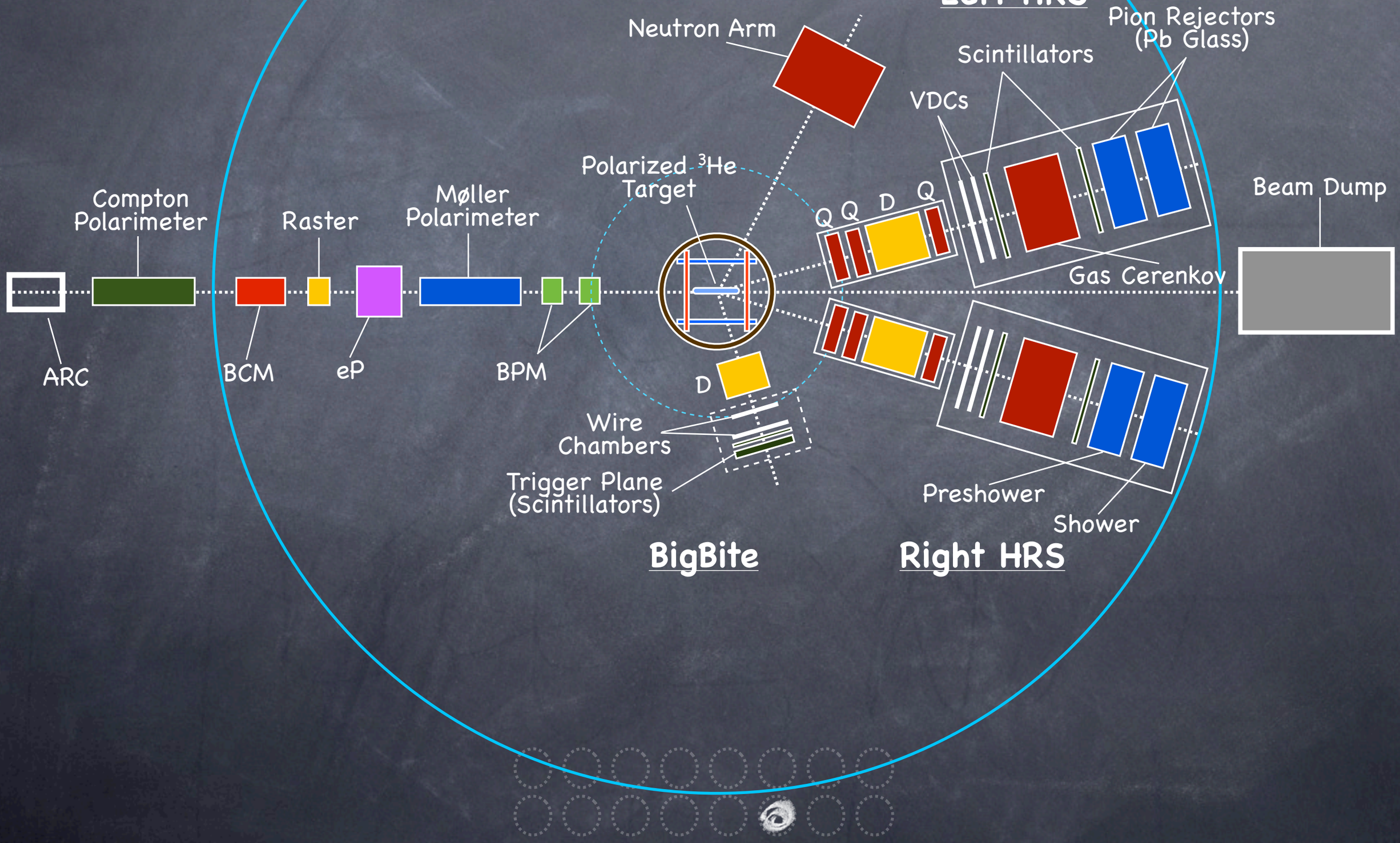
- σ_0 Unpolarized Cross Section
- $\vec{S}$ Spin of Target
- h Helicity of Electrons
- $\vec{A}^0$ Asymmetry when Target Only Polarized
- A_e Asymmetry when Beam Only Polarized
- $\vec{A}$ Asymmetry when Beam and Target Polarized

In PWIA, only part of $\vec{A}$ that is nonzero is $A_{x,z}$ since $S_x \perp \vec{q}$ and $\vec{S}_z \| \vec{q}$

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

$(\pm,\pm)$ refer to beam helicities and projection of target spin on quantization axis

Hall A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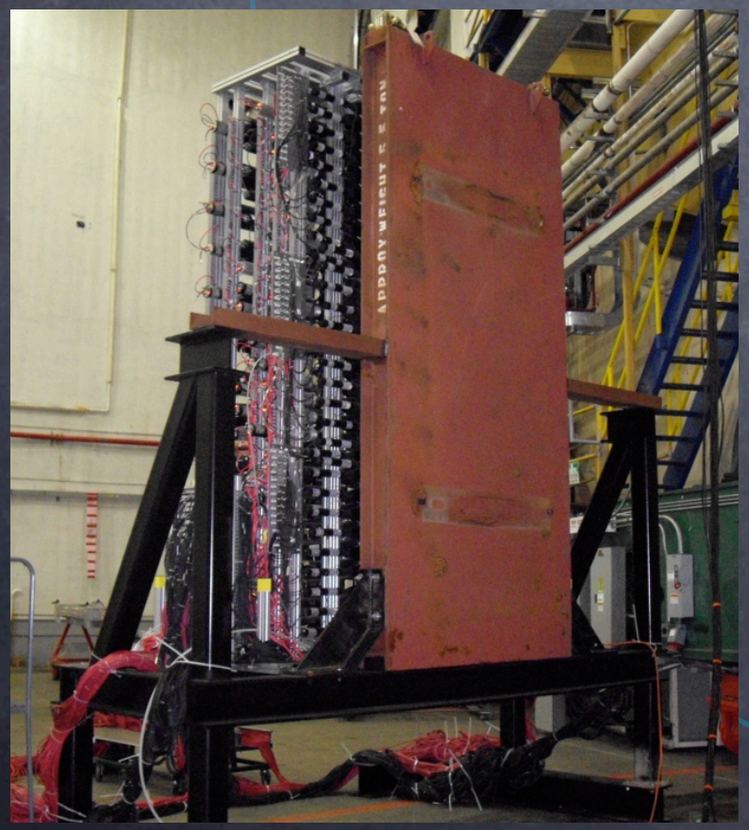
ARC
BCM
eP
BPM
D
Wire
Chambers
Trigger Plane
(Scintillators)
Preshower
Shower
BigBite
Right HRS

Neutron Array

- Detects Neutrons from $^3He(e,e'n)pp$
- Along with RHRS allows a G_E^n Measurement to be made



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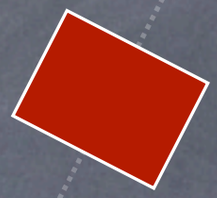
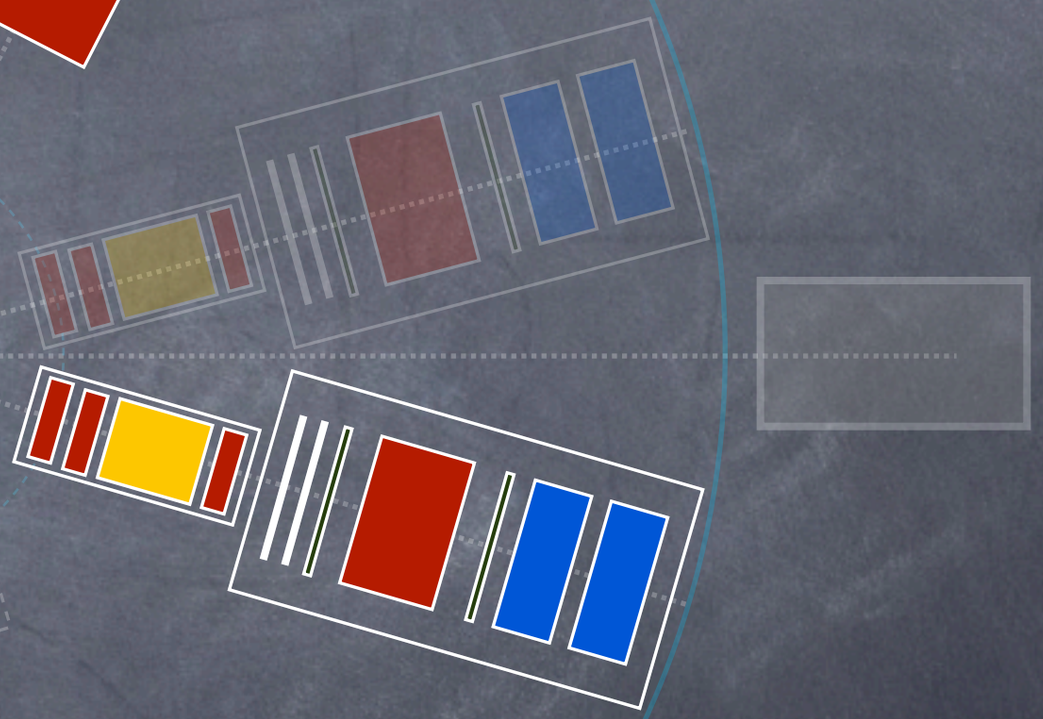
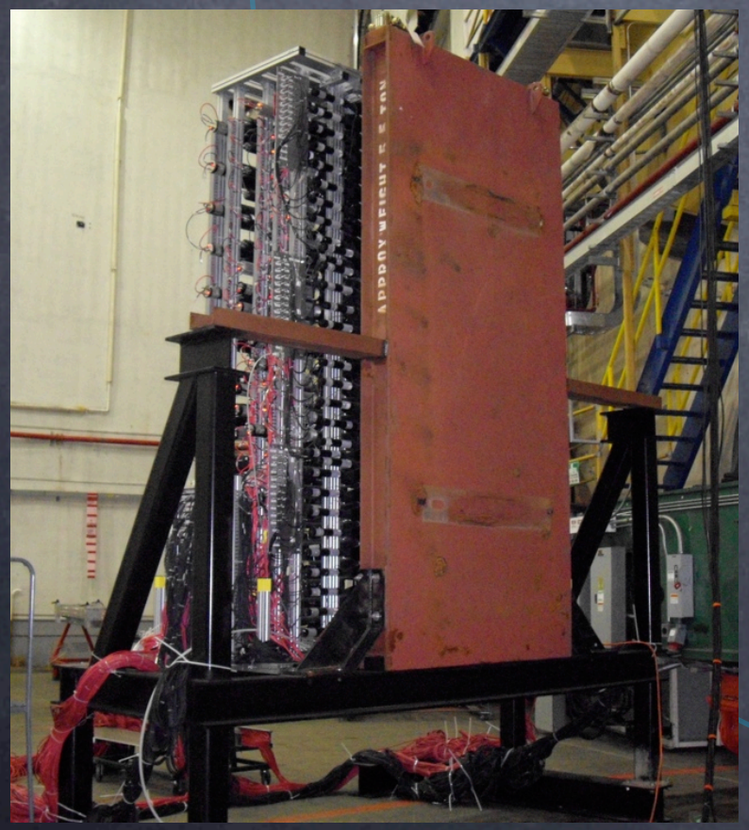


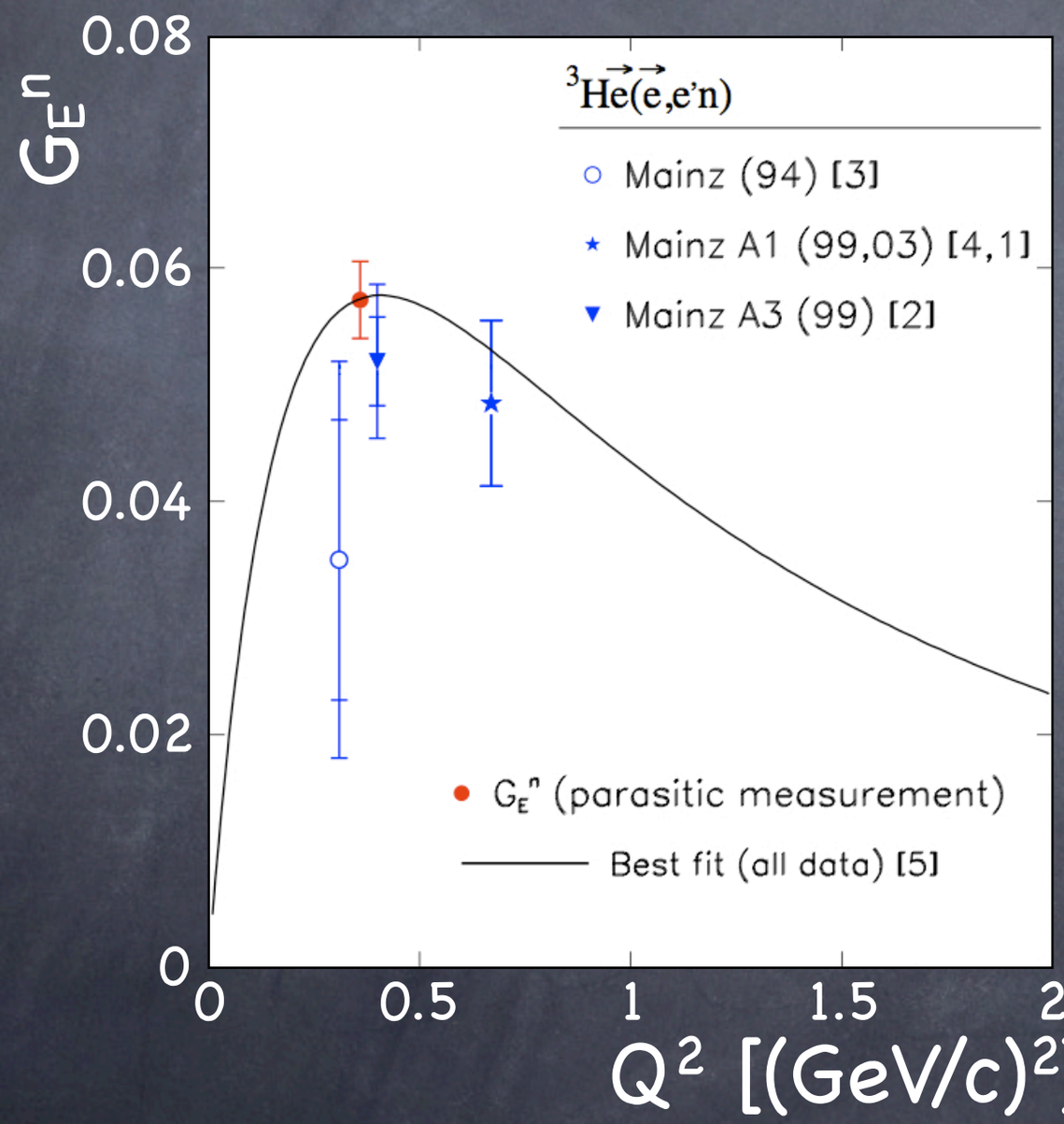




RHRS

- Detects Elastically Scattered Electrons from $^3He(e,e'n)pp$
- Angle at 12.5°

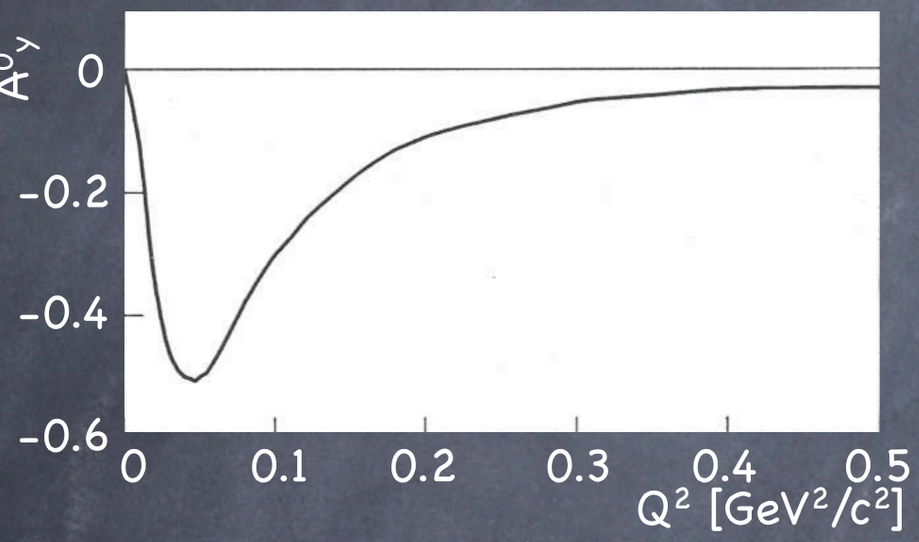
G_E^n Point for Free!



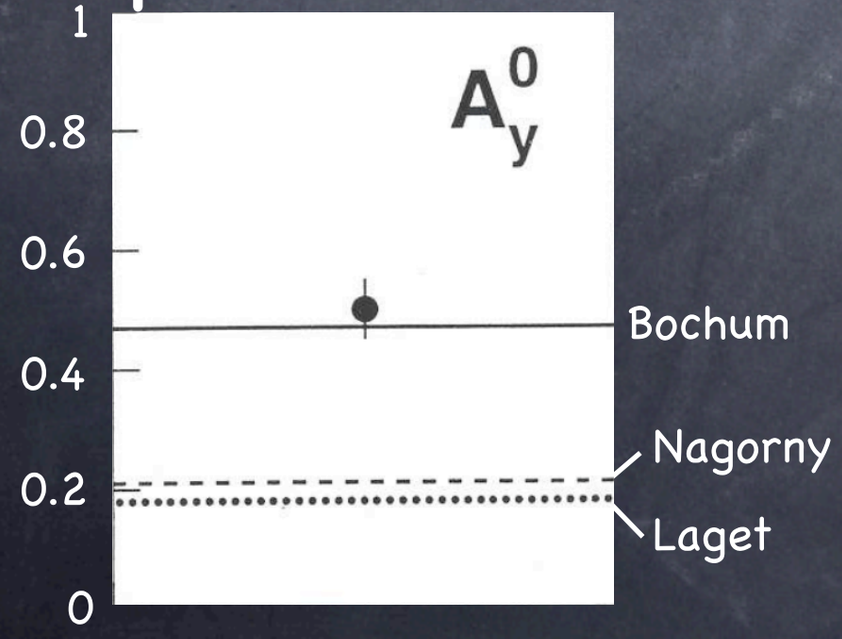
- Optimum BigBite Angle is 64.2°
  - BigBite at 72.8° with Acceptance of 68° to 78°
- Optimum Central Momentum is E′=2.201 GeV
  - HRS at E′=2.294 GeV with Acceptance of 2.191 GeV to 2.397 GeV

Target Single Spin Asymmetry A_y in $^3He^{\uparrow}(e,e'n)$

PWIA Prediction



Experiment (0.2 GeV^2/c^2)



- As of yet, no measurements of A_y have been done at large Q^2
- JLab will obtain high precision data points at 0.75 [GeV/c]^2 and 1.0 [GeV/c]^2
- Data will test state of the art calculations at high Q^2
  - Neutron form factor extractions Must correctly predict this asymmetry

Beam	
Polarization [%]	>= 75%
Beam polarimetry (Compton/Møller)	both
Helicity flip scheme (delayed/quartet/duo)	quartet (?)
Energy range [GeV]	2.4 GeV only
Energy measurement (Arc/EP)	both
Current range [μA]	1-12
Spot size (h x v) [σ] [μm]	100 μm (?)
Raster size (square/round) (h x v/ø) [mm]	< 4 mm diameter
Energy spread [σ]	< 1e-4
Energy lock	on

Targets (specify thickness)	
Photon radiator	no
LH2 (4/15/20 cm)	no
LD2 (4/15/20 cm)	no
Helium-3/4 (4/10/15/20 cm)	no
Target ladder angle (w.r.t. beam)	90°
Solid targets (specify each)	C, Ta, BeO
Polarized Helium-3 target (25/40 cm)	40 cm length, min. 35% polarization
Reference Cell (same length)	H & D

Spectrometers (specify required detectors)

HRS-L		**HRS-R**	
Angle range [°]	15° fixed	Angle range [°]	12.5° fixed
Momentum range [GeV/c]	2.294 fixed	Momentum range [GeV/c]	2.332 fixed
VDC1	yes	VDC1	yes
VDC2	yes	VDC2	yes
S0	not needed	S0	not needed
S1	yes	S1	yes
S2	yes	S2	yes
Gas Cherenkov (long/short)	yes (either)	Gas Cherenkov (long/short)	yes (prefer long)
A1	no		
A2	no		
FPP	no		
Preshower/Shower	yes	Preshower/Shower	yes

Trigger/DAQ	
Coincidence/single	HRSL+BigBite and HRSL+ndet coincidence, HRSR single-arm
Define trigger	electron in HRSL and ((anything in BigBite) or (anything in ndet))

Other Instrumentation

BigBite Spectrometer with 2 pairs of MWDCs and E/dE scintillator planes at about 73°
Neutron detector behind BigBite at roughly the same angle