Probing ^3He Ground-State in Spin-Asymmetry Measurements in Jefferson Lab

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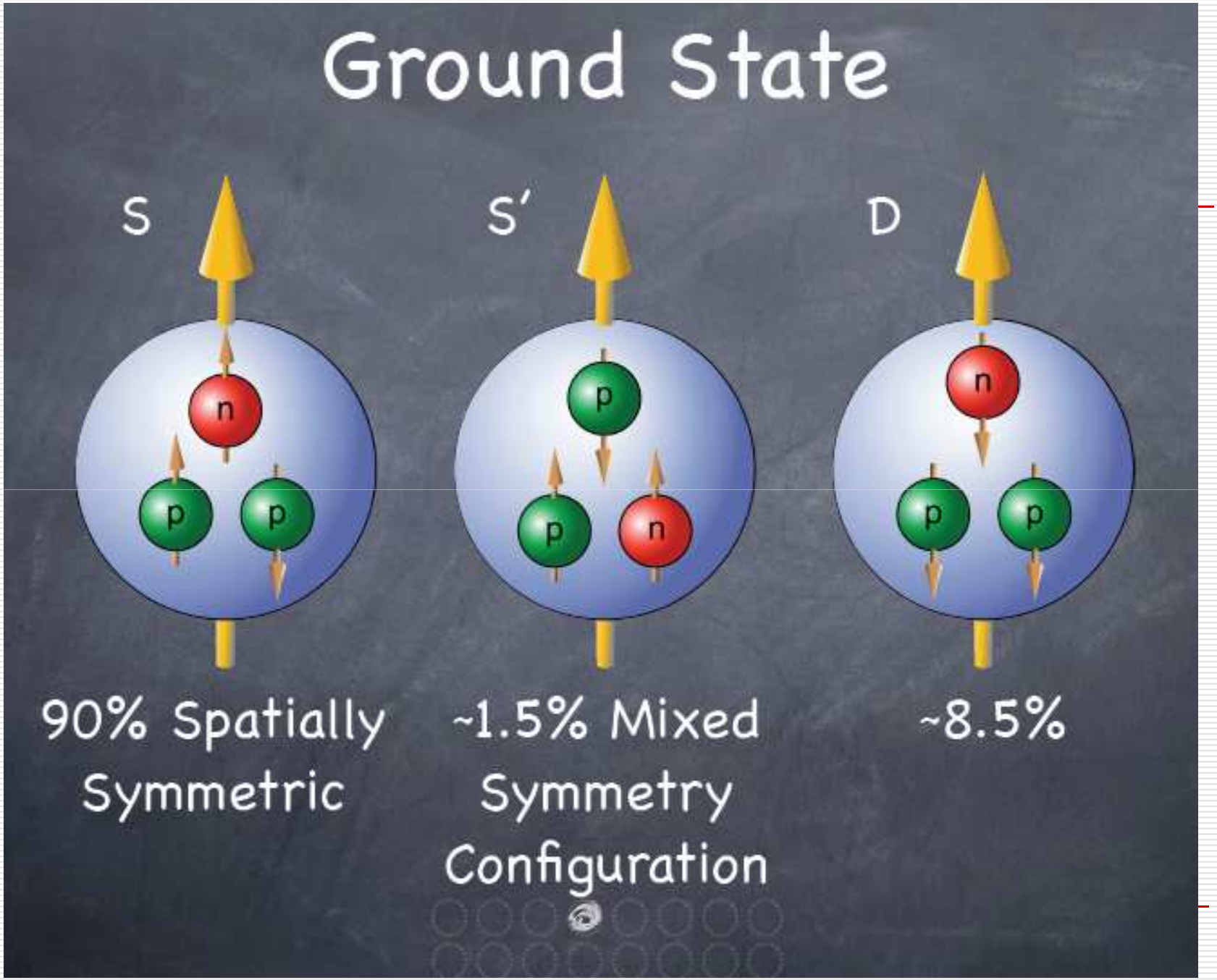
Outline

- Physics motivation
- Experimental set-up
- Conclusion

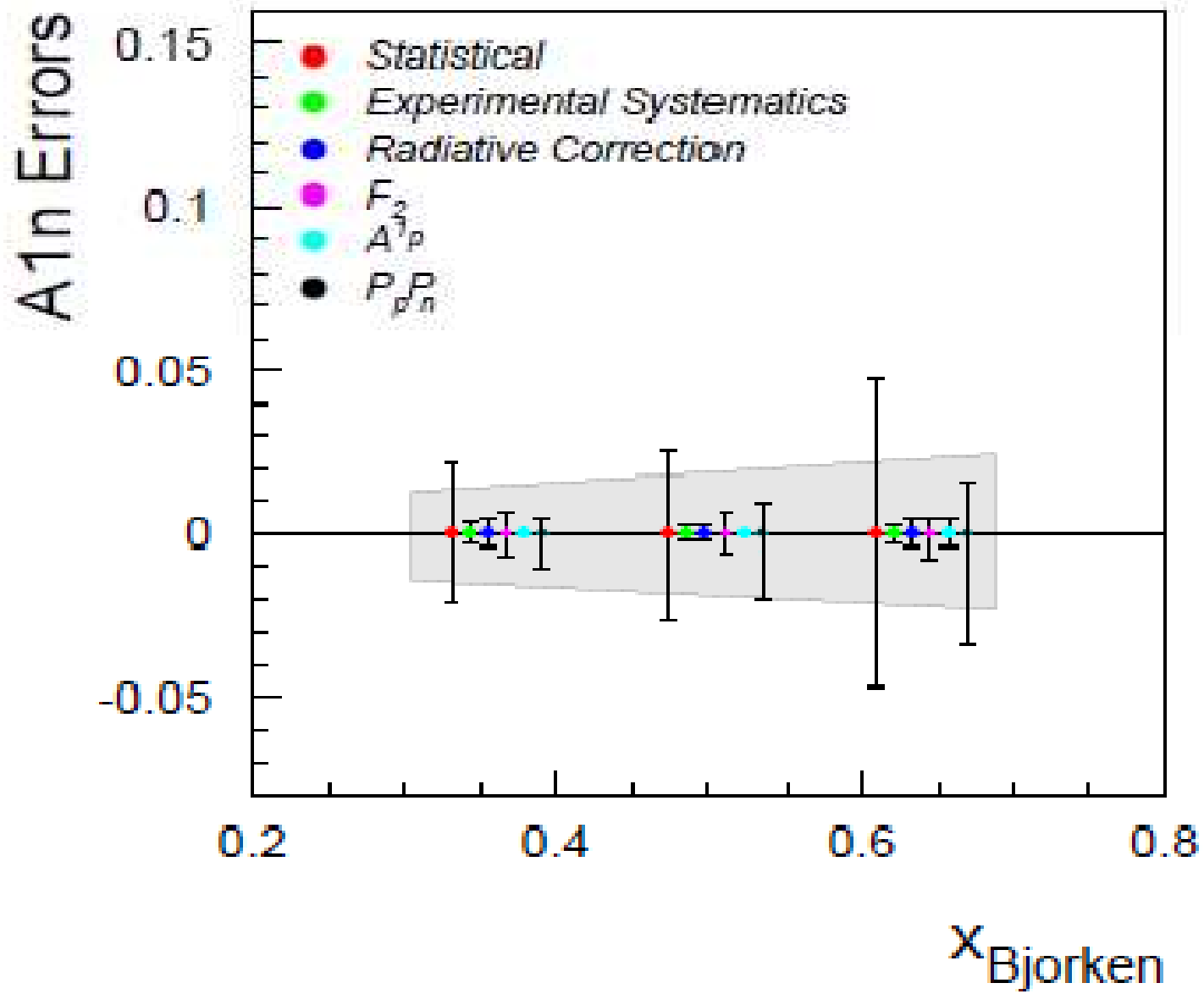
Physics motivation

- A variety of $^3\mathrm{He}$ based experiments seeking to extract neutron information rely on a perfect theoretical knowledge of the ground state spin structures of $^3\mathrm{He}$
- Fadeev calculations predict three components in ground-state wave-function. Understanding the role of S’ and D states helps us understand “standard model” of few-body theory
- Double polarization measurements has large sensitivities to both (S’ and D) components

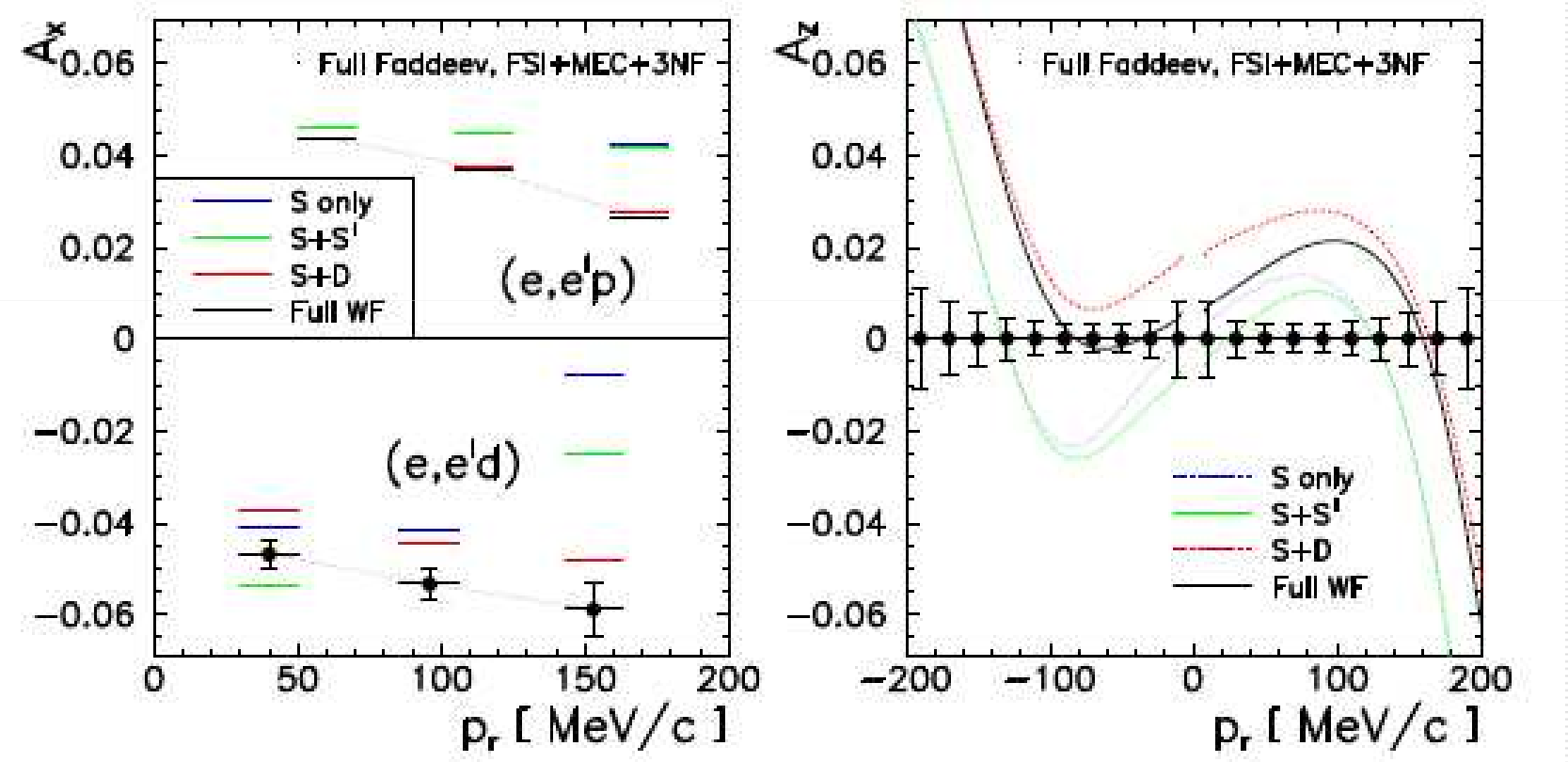

Ground State
S
S'
D
n
p
p
p
n
n
p
p
90% Spatially Symmetric
~1.5% Mixed Symmetry Configuration
~8.5%

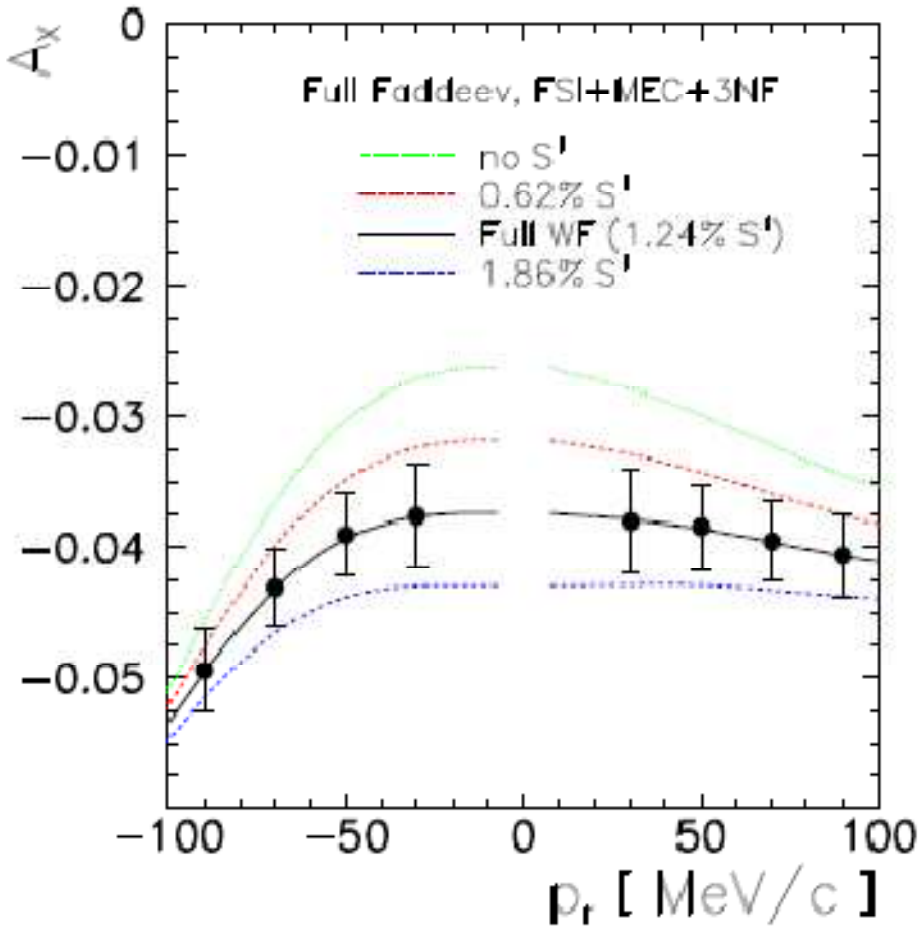
^{3}He target in related measurements

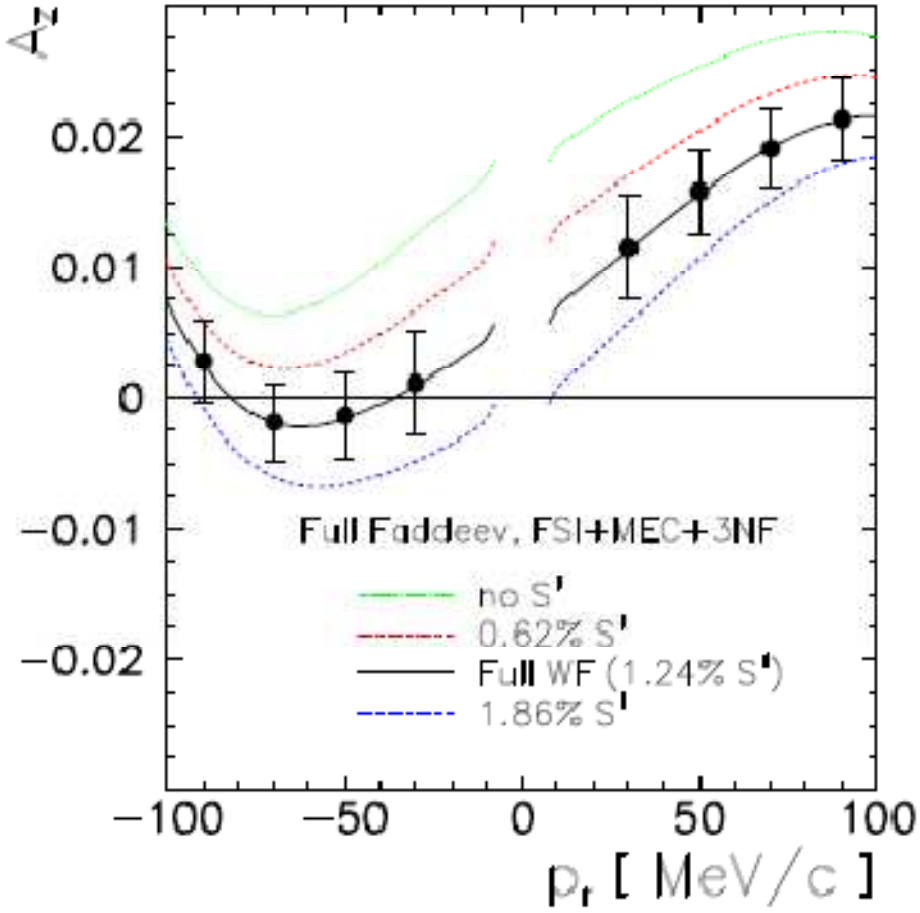
- Elastic scattering: to measure neutron electromagnetic form factors
- Deep inelastic scattering (DIS): to probe polarized nucleon spin structure
- Problem: in E99-117 experiment, leading error comparable with the uncertainty of polarization of neutron and proton


A1n Errors
0.15
0.1
0.05
0
-0.05
0.2
0.4
0.6
0.8
Statistical
Experimental Systematics
Radiative Correction
F_2
A^3_p
P_pP_n
$x_{Bjorken}$

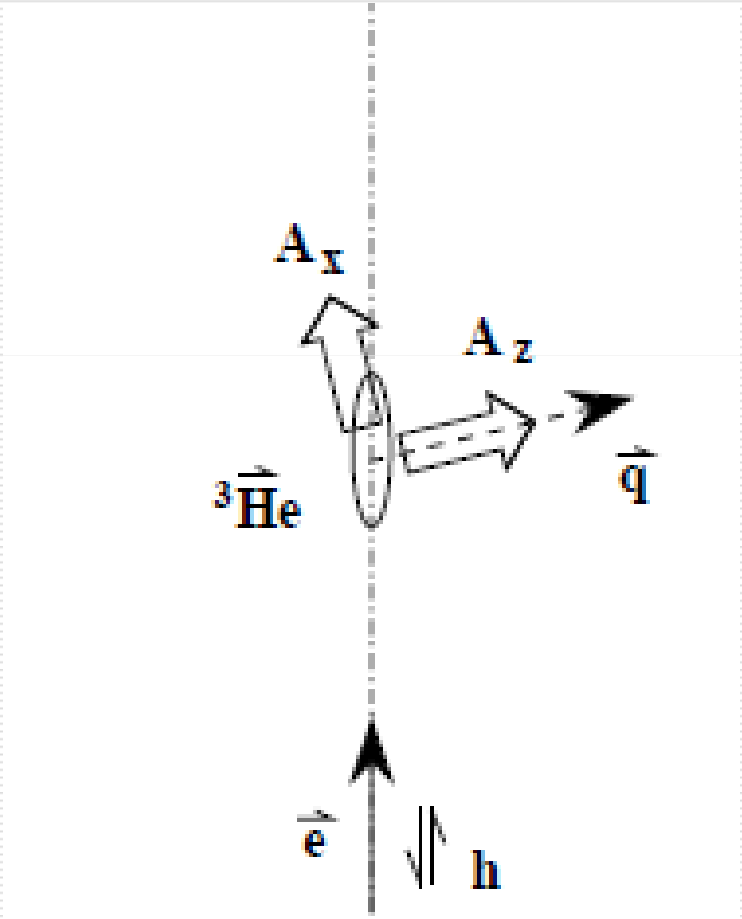
Helium Asymmetry sensitive to S’ and D waves (theoretical calculation)




A_y^x
0
−0.01
−0.02
−0.03
−0.04
−0.05
Full Faddeev, FSI+MEC+3NF
no S'
0.62% S'
Full WF (1.24% S')
1.86% S'
−100
−50
0
50
100
p_r [MeV/c]


A_y^z
0.02
0.01
0
−0.01
−0.02
Full Faddeev, FSI+MEC+3NF
no S'
0.62% S'
Full WF (1.24% S')
1.86% S'
−100
−50
0
50
100
p_r [MeV/c]

Non-zero asymmetries, Ax and Az



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

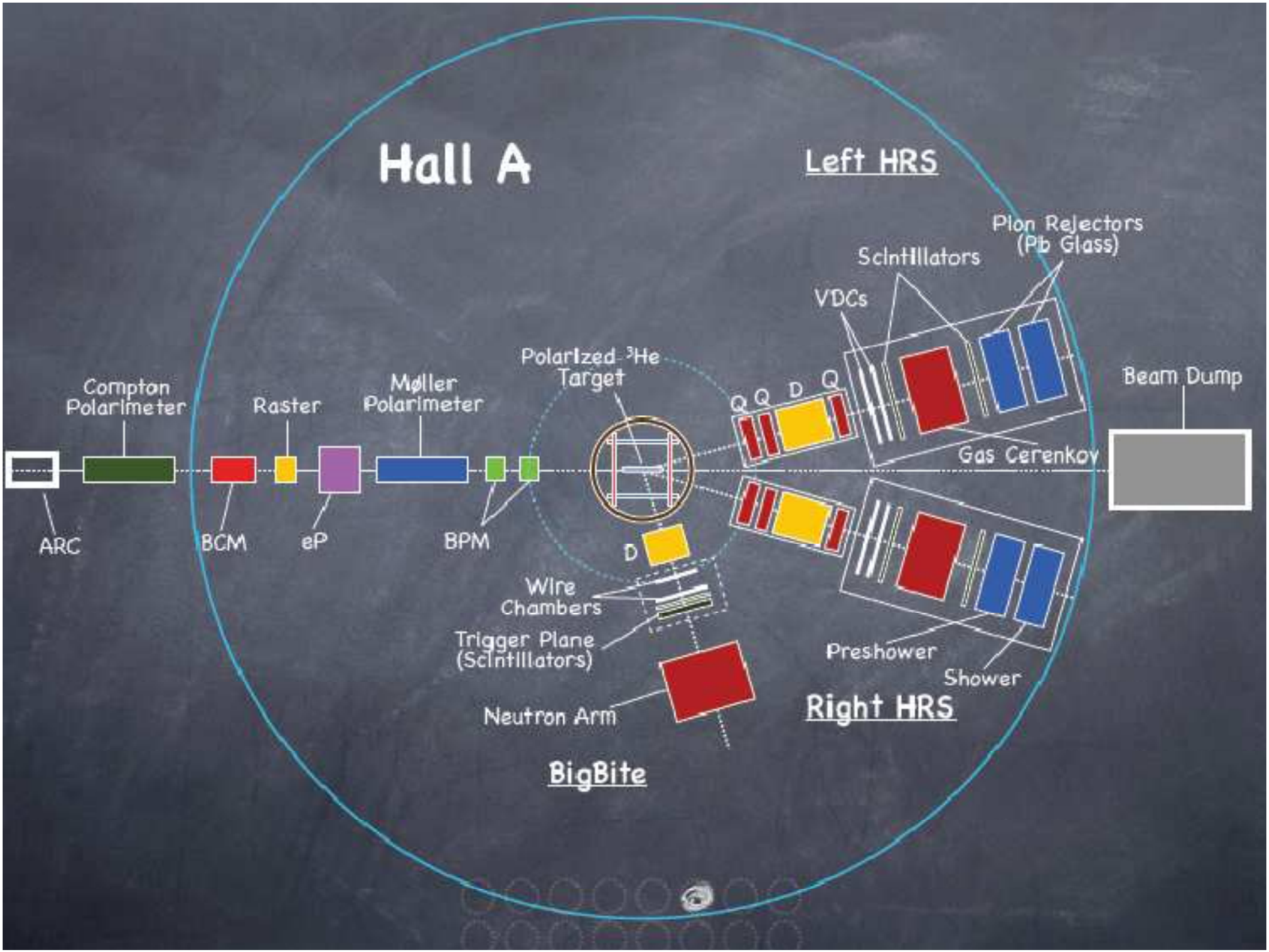
In PWIA, only part of $\vec{A}$ that is nonzero is $A_{x,z}$ since $\vec{S}_x \perp \vec{q}$ and $\vec{S}_z \| \vec{q}$

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

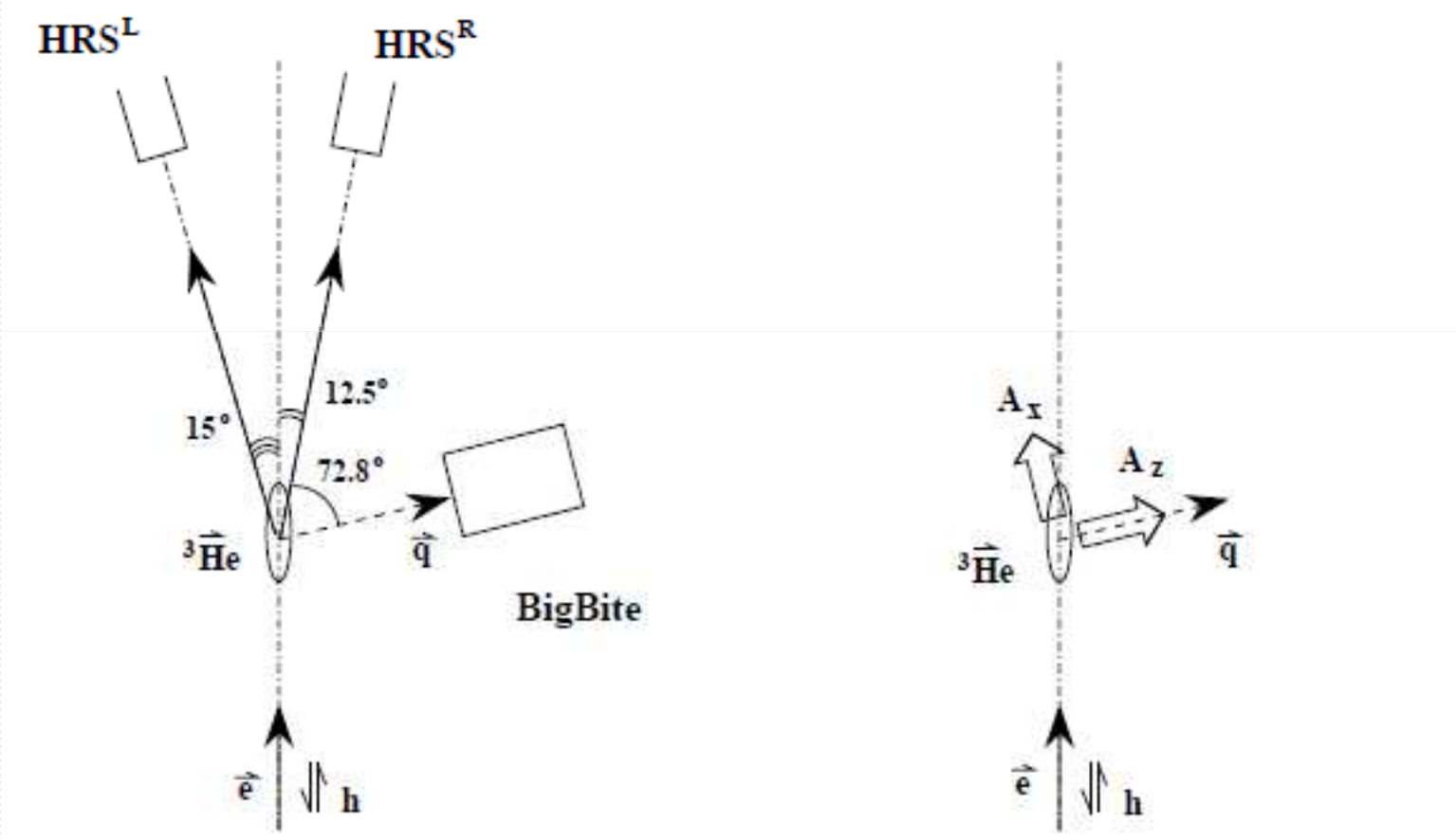
$(\pm,\pm)$ refer to beam helicities and projection of target spin on quantization axis

Experimental Set-up

- Beam energy 2.4 GeV
- Electron scattering angle of 15 degrees
- Momentum transfer of 620MeV/c
- BigBite get kinematics up to ~200MeV/c
- Beam helicity fast-flipped (30Hz)
- Target spin flipped every 24 hours

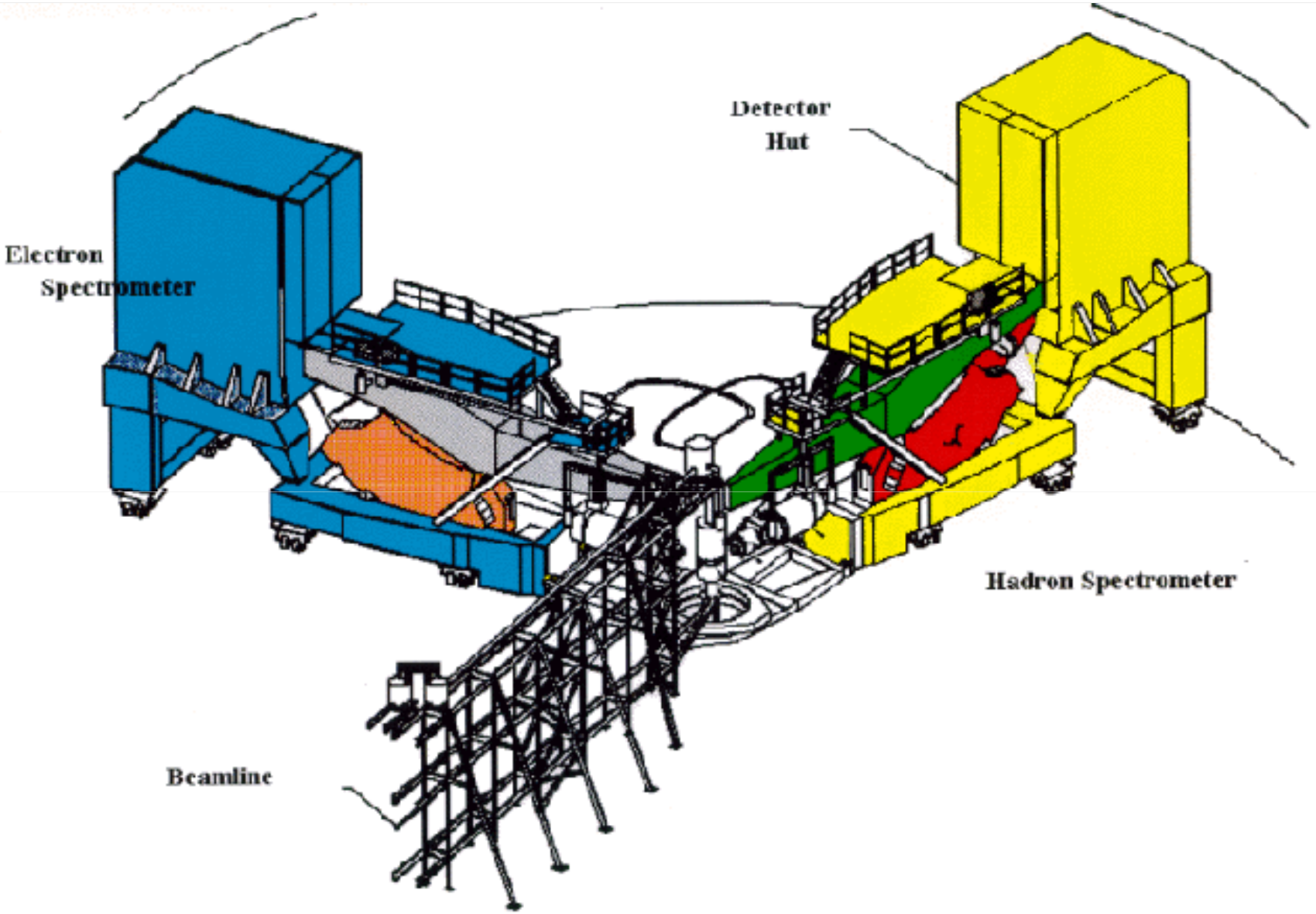

Hall A
Left HRS
Pion Rejectors
(Pb Glass)
Scintillators
VDCs
Polarized ³He
Target
Compton
Polarimeter
Raster
Møller
Polarimeter
Q Q D Q
Beam Dump
Gas Cerenkov
ARC
BCM
eP
BPM
D
Wire
Chambers
Trigger Plane
(Scintillators)
Preshower
Shower
Neutron Arm
Right HRS
BigBite

Detectors scheme



High-resolution spectrometers (HRS)

- Detects scattering electrons with high resolution and relatively low acceptance
- Angular resolution:
  - ~0.6mr in non-dispersive plane
  - ~0.2mr in dispersive plane
- Momentum acceptance: ±4.5%
- Angular acceptance:
  - ~22mr in non-dispersive plane
  - ~60mr in dispersive plane


Detector
Hut
Electron
Spectrometer
Hadron Spectrometer
Beamline

A pair of HRS

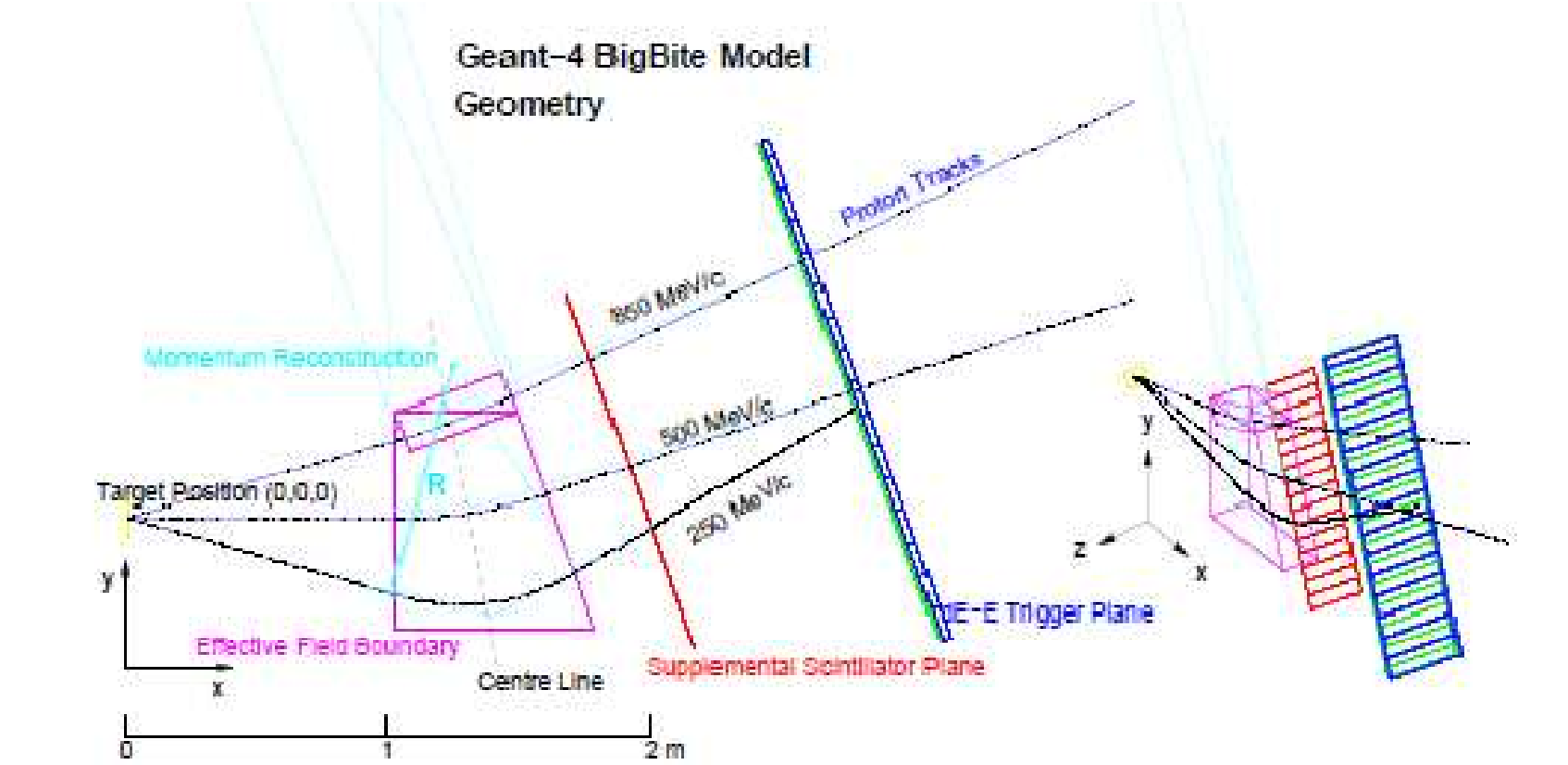
- Right spectrometer (RHRS) measures elastically scattered electrons, monitors the product of beam and target polarization and luminosity
- Left spectrometer (LHRS) measures production electrons

BigBite spectrometer

- Detects deuterons with large acceptance and relatively low resolution
- Solid angle of 96 msr
- Momentum acceptance: 200-900MeV/c
- Two wire chambers and two scintillator planes


APPROX WEIGHT 5.5 TO

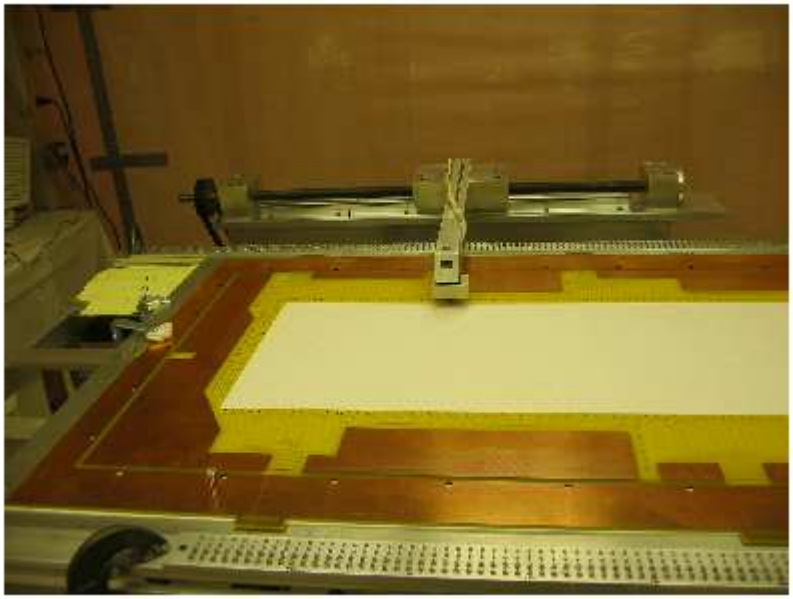
BigBite geometry



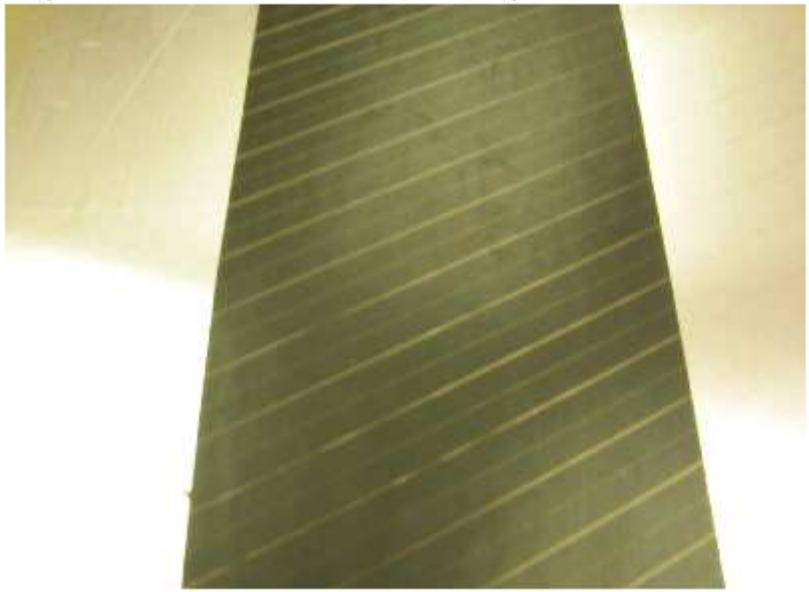
Wire chambers

- Gas: 50% argon and 50% ethane
- Particles produce signals in gas and pass signals on wires
- Wires in three orientations between 30-degree angles
- Detect particle time and position information

140 x 35 cm^2 drift chamber plane

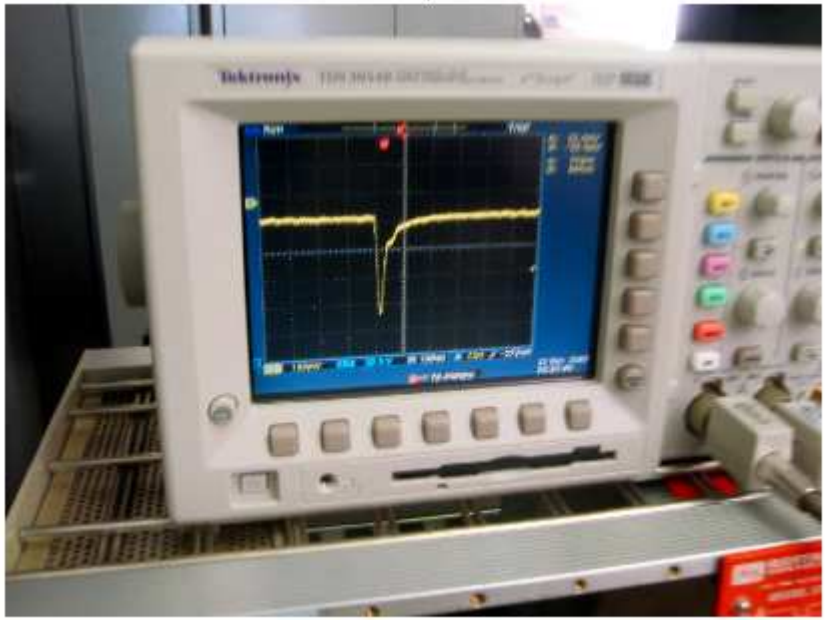


90μ– BeCu field and 20μ–W anode wire



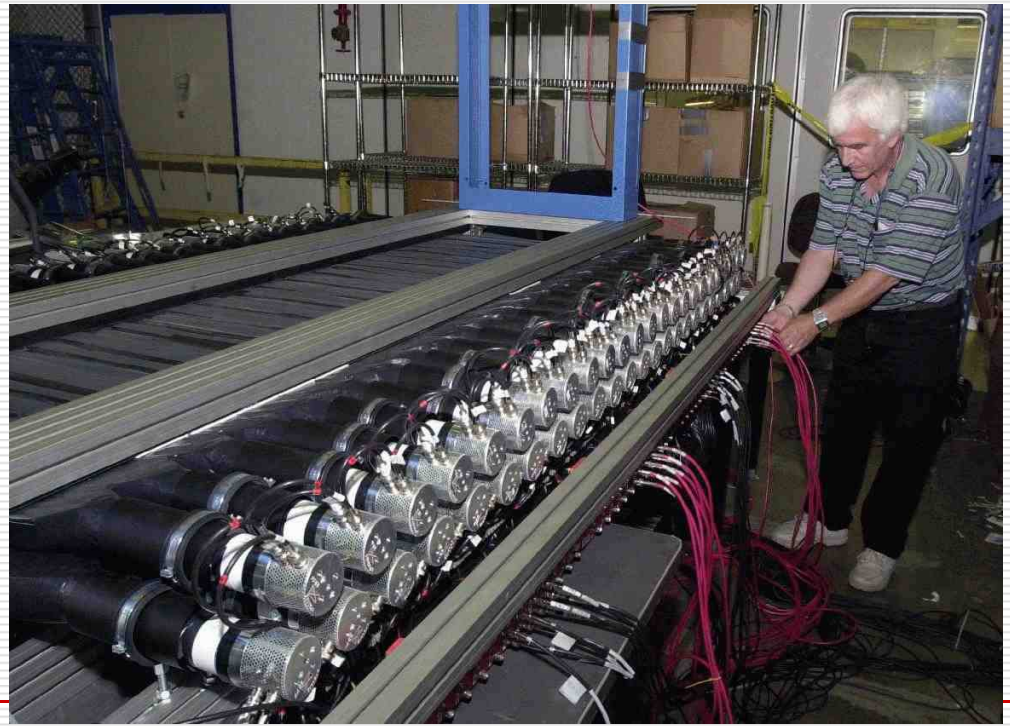
Test set up with radioactive source

100 mv/cm , 100 ns/cm



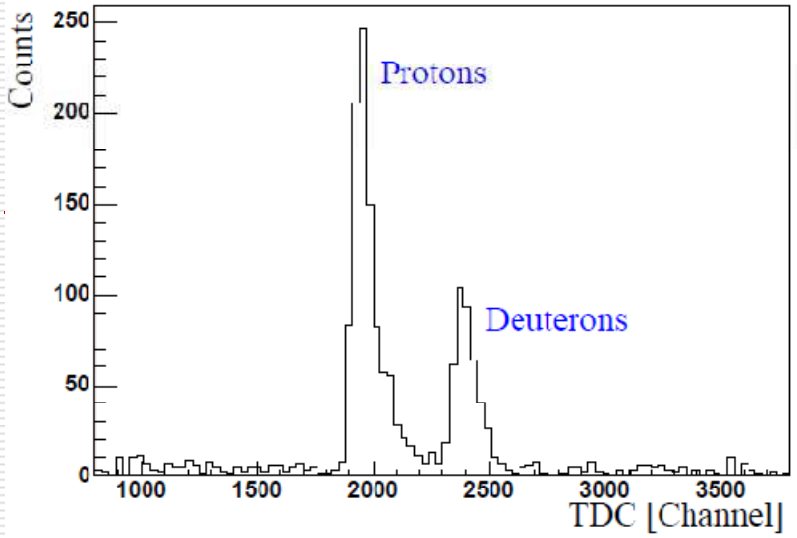
BigBite trigger plane

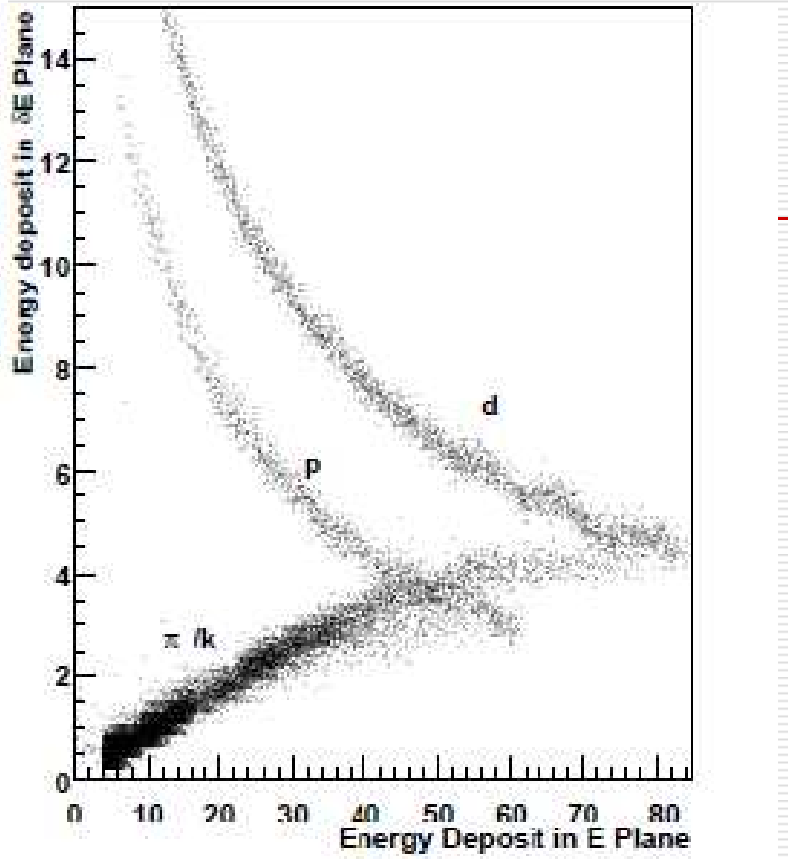
Two scintillator planes: E and dE plane



Scintillator planes

- Two planes in parallel, E and dE
- Each plane has 24 scintillator bars
- “Plastic”, produces light when a particle comes in
- Different scintillator bars detect position information, and also time information





Differentiate between protons and deuterons by time-of-flight method and E-dE plot

Beam-time allocation

- 15 PAC days

Table 3: Beam-time allocation.

	Beam-time [days]	Radiative loss [days]	Total beam-time [days]
A_x	5.5	1.5	7.0
A_z	5.5	1.5	7.0
Calibrations	1.0	N/A	1.0
			15.0

Conclusion

- Using double-spin asymmetry measurements to probe minority states
- HRS and BigBite as main detecting devices
- Experiment: May 4^{th} ~ June 15^{th}
- Webpage: http://hallaweb.jlab.org/experiment/E05-102/