Helicity/Beam Polarization extraction/logging

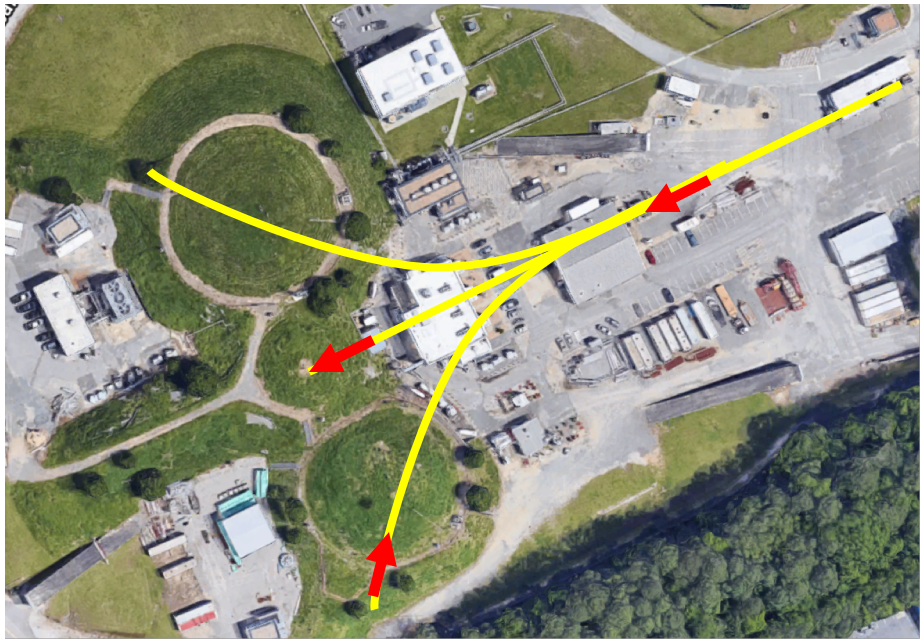
Polarized beam at JLab

$P = (N_e\uparrow - Ne\downarrow)/(N_e\uparrow + Ne\downarrow) \rightarrow 90\%$

For Fall 2018 running, longitudinally polarized beam was delivered for benefit of Hall B.

Hall B made periodic measurements of polarization. ~ 88%
Hall C did not measure polarization

Spin processes in Hall C arc, but beam still nearly longitudinally polarized
(Most interesting physics is with beam polarization || to beam direction.)

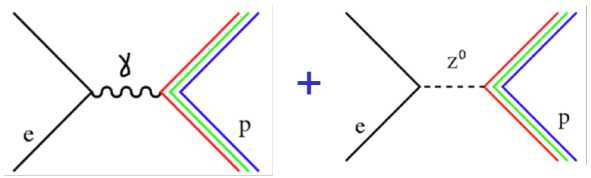


Spin precession
$\theta_{prec} = \gamma(g/2-1)\,\theta_{bend}$
@ 10.6 GeV $\gamma = 20744$, $\theta_{bend} = 37.5°$
$\theta_{prec} = 902°$ 2.5 full rotations

Physics with longitudinal polarized electrons - 1

1. $(\vec{e}, e')$ - small PV asymmetry

$$A_z = \frac{\sigma^+ - \sigma^-}{\sigma^+ + \sigma^-}$$



Small asymmetries <= 10^{-6}

e.g. Standard model tests

2. Spin transfer $(\vec{e}, e'\vec{p})$ $(\vec{e}, e'\vec{n})$

e.g. Electric form factors of proton and neutron

G_E^p G_E^n

Physics with longitudinal polarized electrons - 2

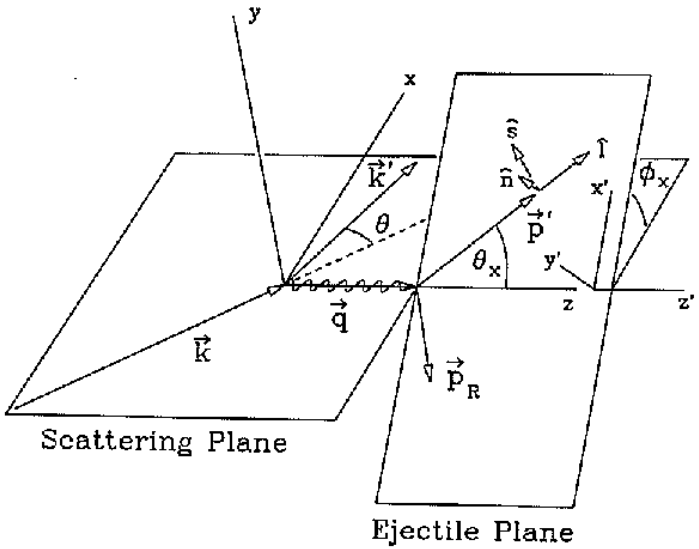
3. Polarized target $\vec{p}(\vec{e},e')$ $\vec{n}(\vec{e},e')$

   Nucleon spin structure functions g_1, g_2

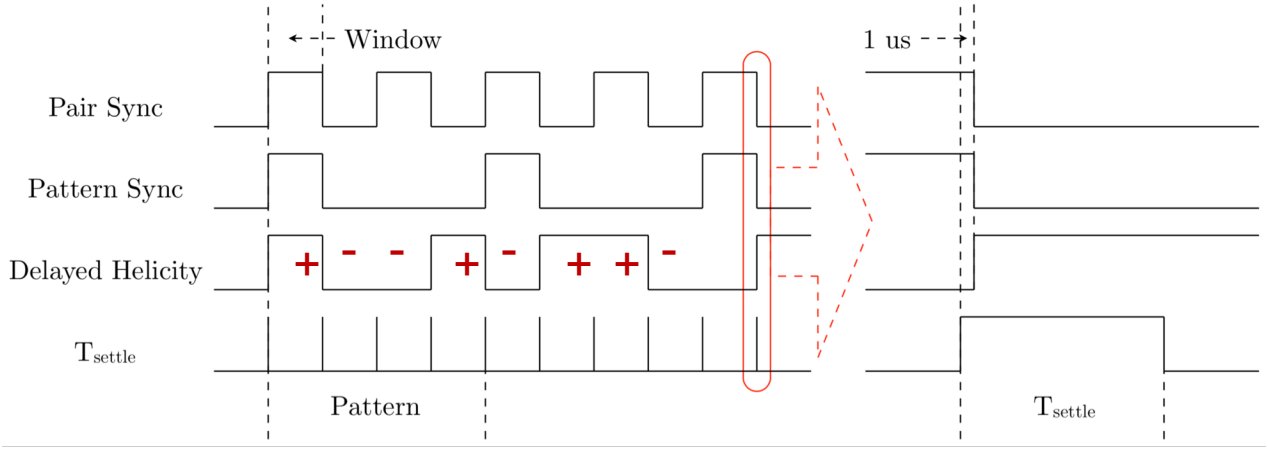
   Upcoming Hall C A_{1n} and d_{2n} experiments

4. Out of plane reactions $(\vec{e},e'x)$

   Hadrons out of plane defined by e, e′ can have beam asymmetry with sin(ϕ) dependence



Helicity flipping



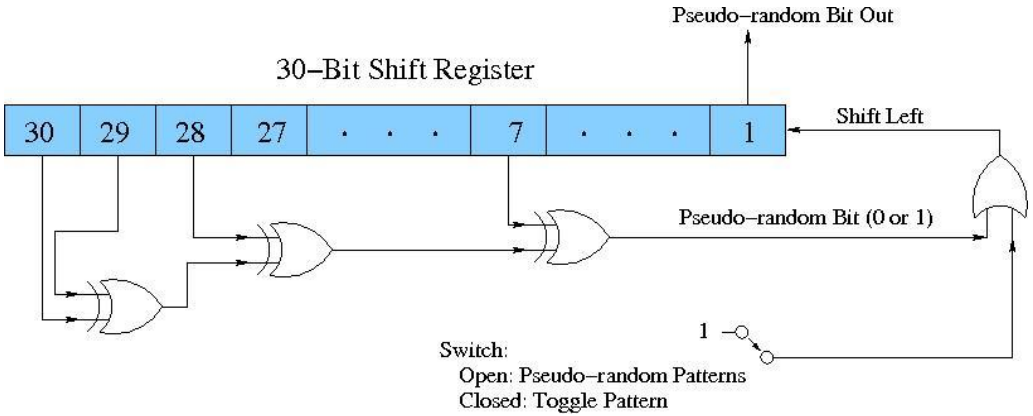
Injector randomly flips helicity/polarization direction at typically 30Hz

Signals are delivered to indicate helicity and to indicate when helicity is flipping

Helicity sequence can be in patterns, e.g. quartets + - - + - + + -

Helicity reporting can be delayed.

Delay Helicity Reporting



See Indico minutes for references on helicity signal generation

Current experiments (SIDIS, KaonLT) events tagged by delayed helicity and T_{settle} status (Sawatzky/Pooser)

No trigger during T_{settle} – planned for A1n/d2n

Still able to decode helicity with aid of high resolution (4ns) DAQ clock.

Helicity scalers (for charge asymmetry) in DAQ, but no analysis software yet.

Decoding helicity in hcana

Implemented in classes THcHelicityReader & THcHelicity

To use, add THcHelicity to trigger apparatus:

```
THaApparatus* TRG = new THcTrigApp("T", "TRG");
...
THcHelicity* helicity = new THcHelicity("helicity", "Helicity Detector;
TRG->AddDetector(helicity);
```

Hardware addresses (roc/slot/add) of signals hardwired in THcHelictyReader.

Parameters helicity_delay & helicity_freq. Defaults are 8 and 29.5596.

Tree variables:

`T.nqrt`	Where in quartet (0-3)
`T.hel`	Actual helicity (-1, 1, 0 if in T_settle or not predicted)
`T.helrep`	Reported delayed helicity
`T.helpred`	Predicted delayed helicity – should agree with helrep
`T.mps`	1 if event during T_settle

hcana helicity todo list

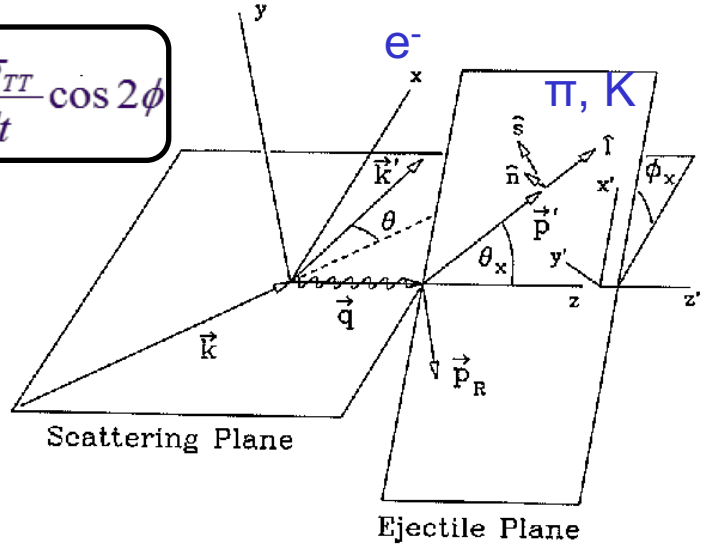
1. Run time configuration of helicity signal hardware addresses.
   Either with parameters or map file
2. Parameter to flip sign of helicity
3. Get IHWP position from EPICS – flip helicity sign if “IN”
4. Back predict helicity seed to recover helicity for first 4 seconds of each run
5. Implement helicity scaler decoding for current (KaonLT/SIDIS) DAQ configuration. (Optional)
6. Implement helicity scaler decoding for A1n/d2n DAQ configuration. (Required)

Beam Single Spin Asymmetry – Kaon LT

$$2\pi\frac{d^2\sigma}{dtd\phi} = \varepsilon\frac{d\sigma_L}{dt} + \frac{d\sigma_T}{dt} + \sqrt{2\varepsilon(\varepsilon+1)}\frac{d\sigma_{LT}}{dt}\cos\phi + \varepsilon\frac{d\sigma_{TT}}{dt}\cos 2\phi$$

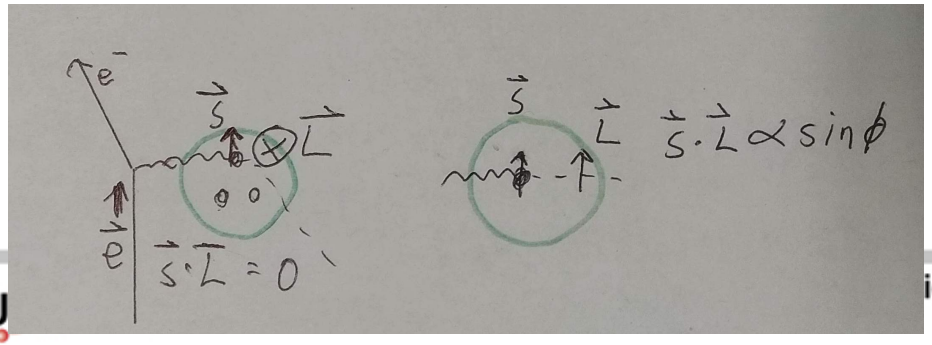
Additional term if beam polarized $\quad h\,\frac{d\sigma_{LT'}}{dt}\sin\phi$

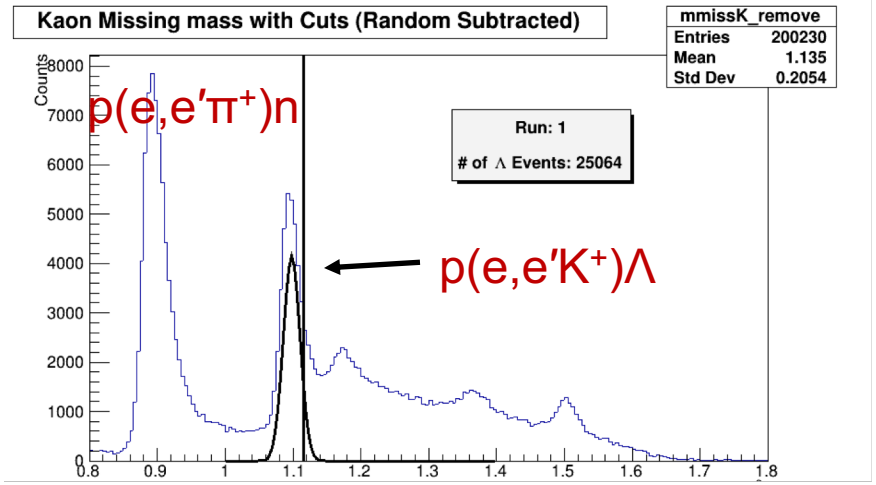
Measure $\quad A(\phi) = \frac{\sigma^+(\phi) - \sigma^-(\phi)}{\sigma^+(\phi) + \sigma^-(\phi)}$



My naïve understanding of why there is an out of plane asymmetry

Spin-Orbit force

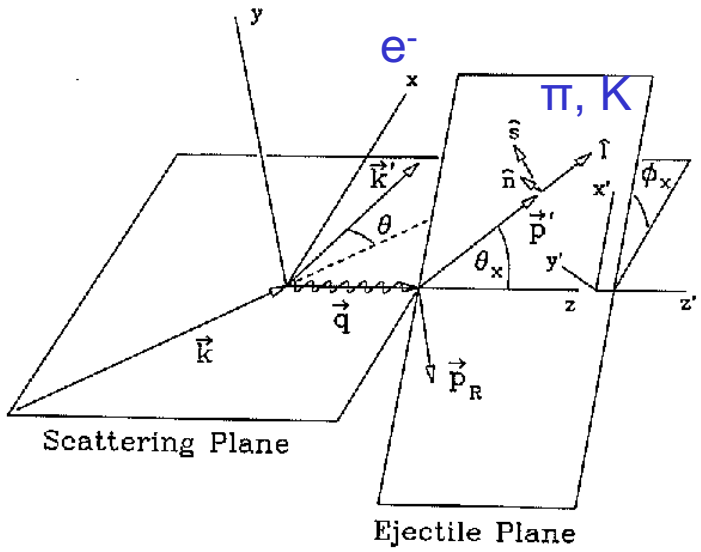


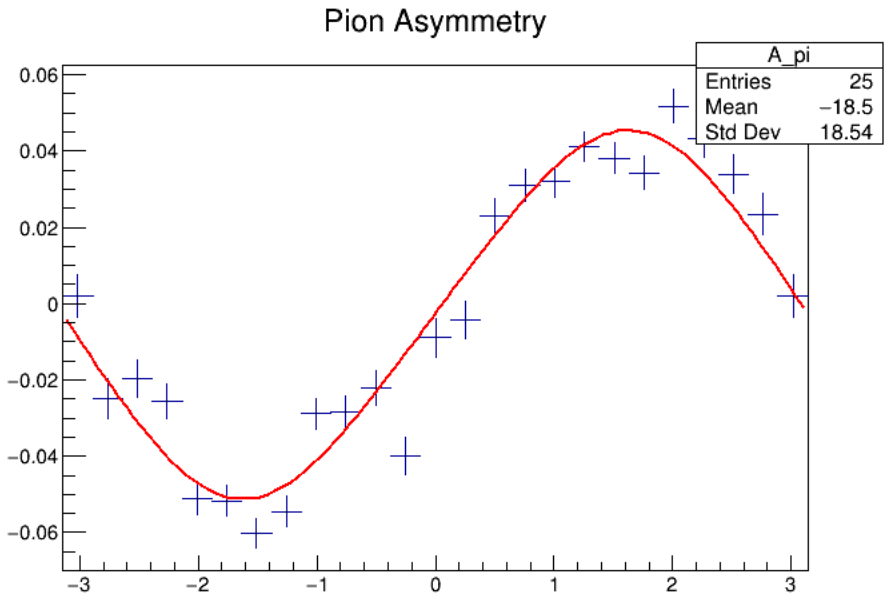


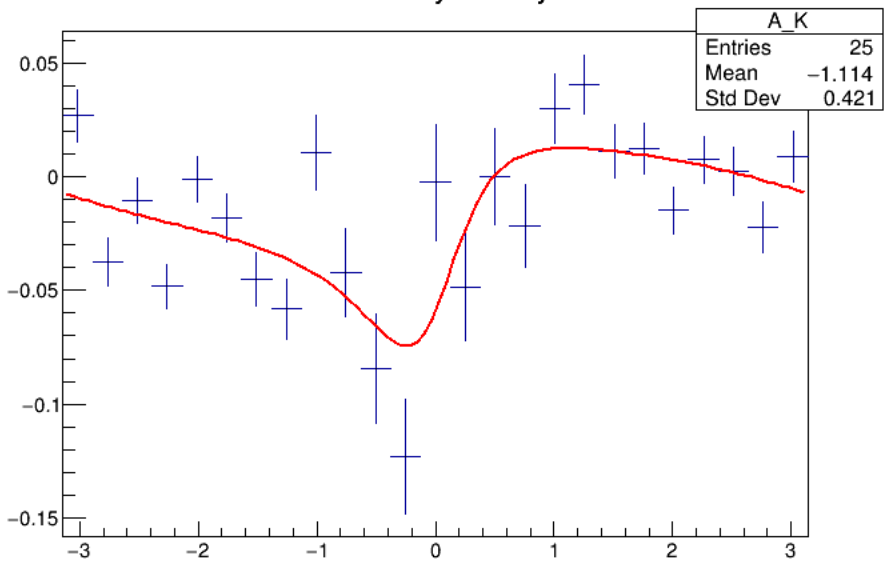
Beam Single Spin Asymmetry

Asymmetries fit to

$$\frac{A + B \sin\varphi}{1 + C\cos\varphi + D\ \cos 2\varphi}$$

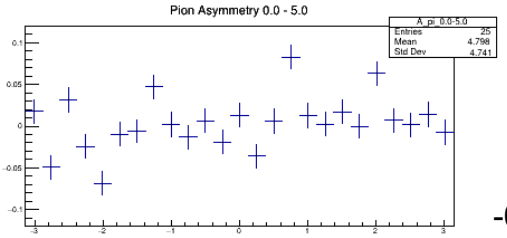






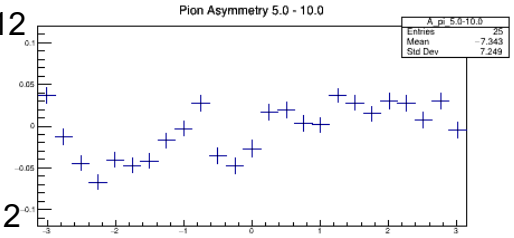
Q^2=3, W=2.32

$\langle\theta_{cm}\rangle$ = 2.5°



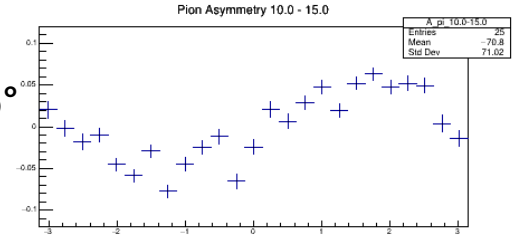
0.12

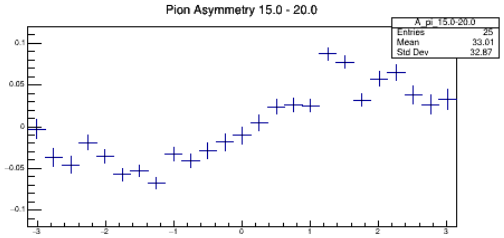
-0.12



$\langle\theta_{cm}\rangle$ = 7.5°

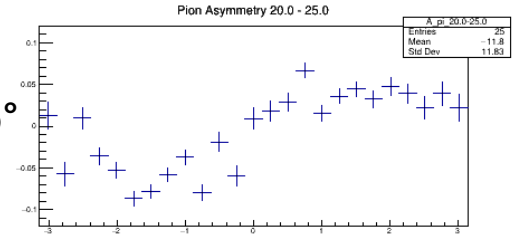
$\langle\theta_{cm}\rangle$ = 12.5°

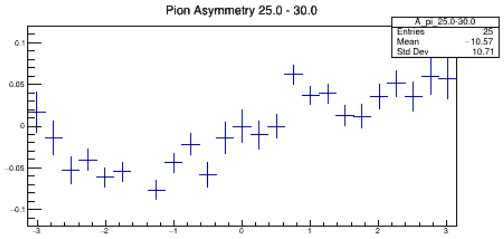




$\langle\theta_{cm}\rangle$ = 17.5°

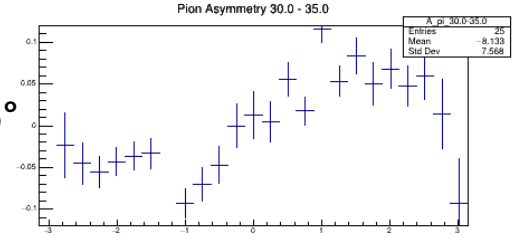
$\langle\theta_{cm}\rangle$ = 22.5°

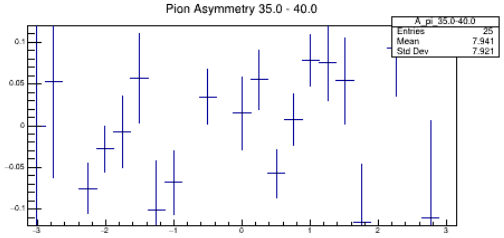




$\langle\theta_{cm}\rangle$ = 27.5°

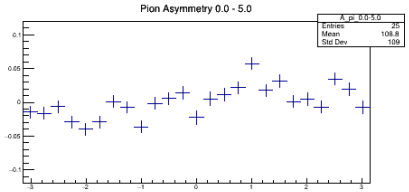
$\langle\theta_{cm}\rangle$ = 32.5°

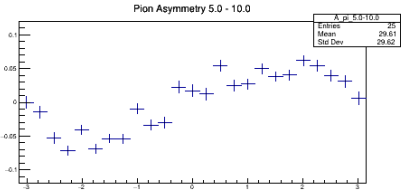


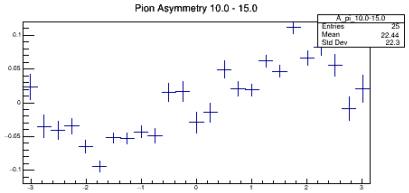


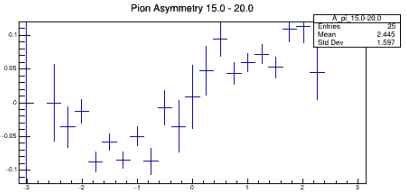
$\langle\theta_{cm}\rangle$ = 37.5°

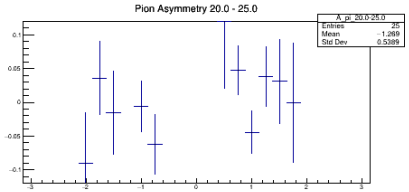
Q^2=3, W=2.32 Q^2=2.115, W=2.95

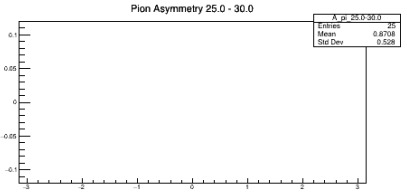


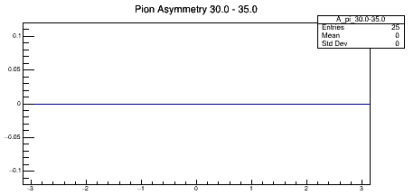


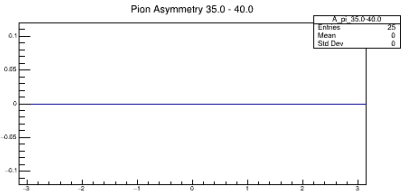


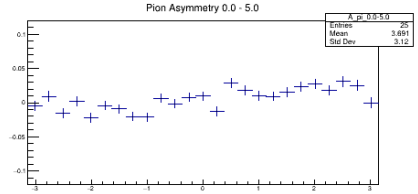


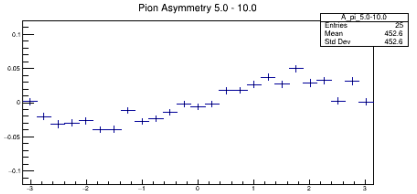


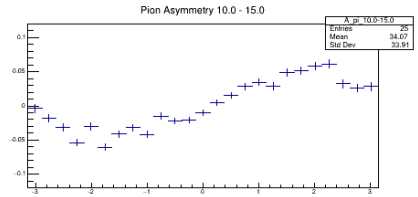


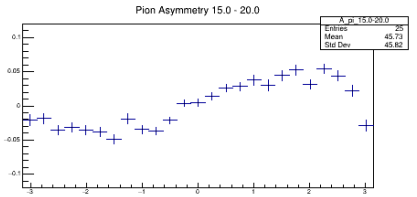


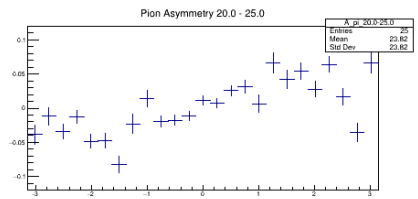


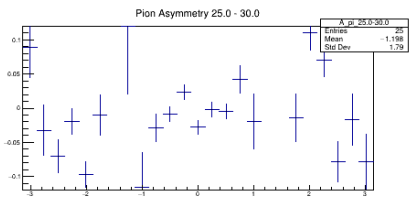


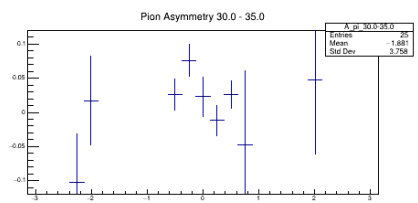


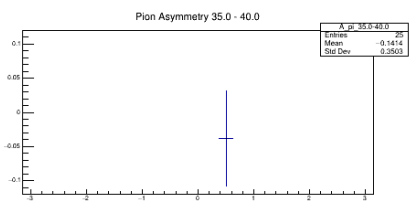




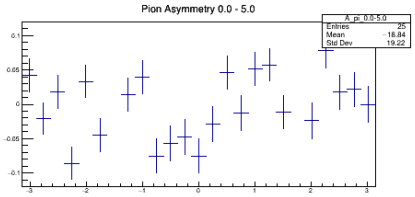


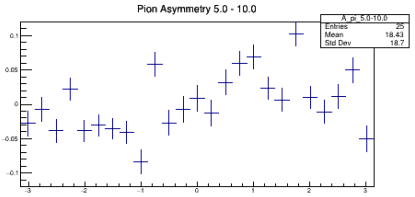


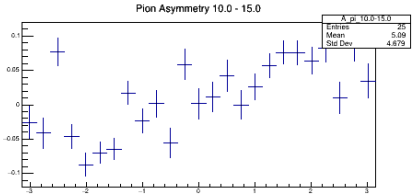


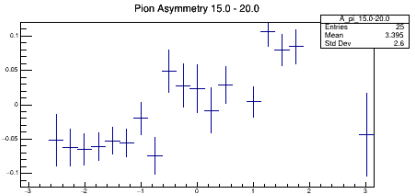


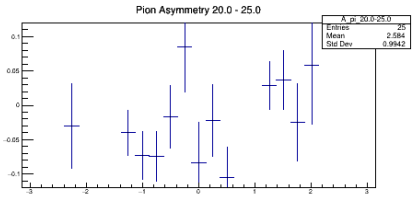
Q^2=4.4, W=2.74

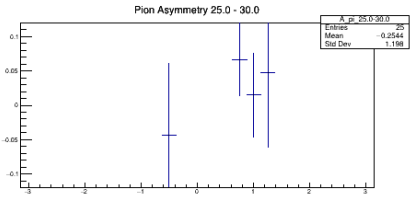


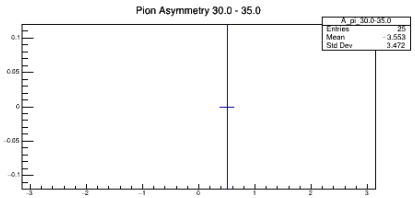


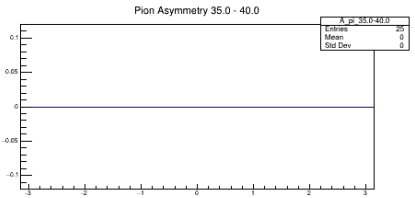




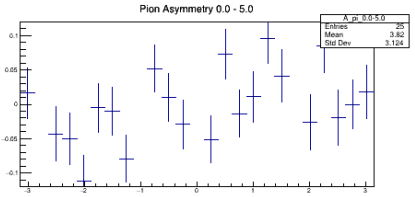


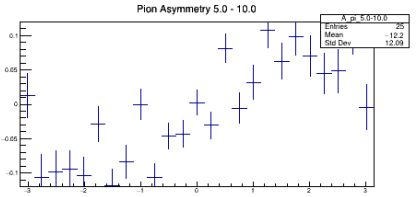


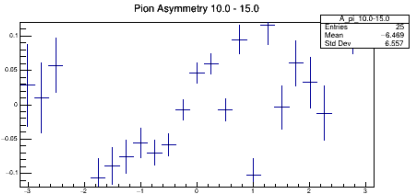


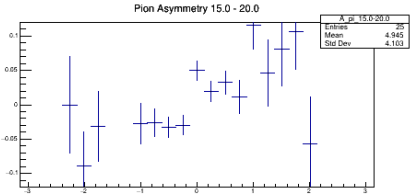


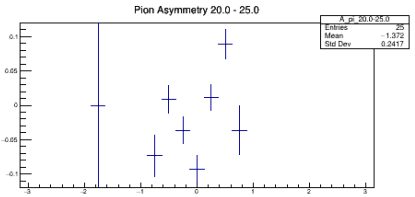
Q^2=5.5, W=3.02

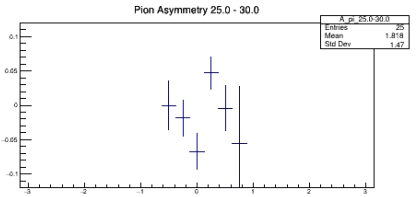


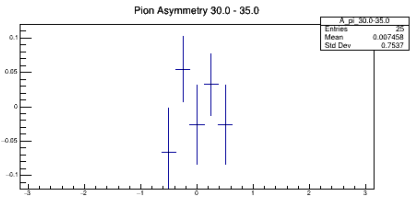


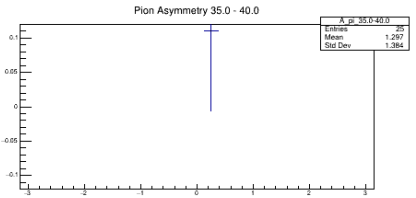












Physics analysis todo list

1. Make best determination of polarization
2. Was beam polarized for Q^2 = 0.5 (3.84, 4.93 GeV)
3. Random background subtraction – dilution
4. Is there a statistically significant Kaon asymmetry?
   Background under Lambda peak includes
   - Radiative tail of misidentified pions
   - Inelastic pions
   - Accidental background
5. Is there a statistically significant asymmetry for high resonances.
6. Compare to Hall B results (6 GeV era + recent data)
   (K. Park et. al., Phys. Rev C **77**, 015208 (2008))

Setting	Low ε data	High ε data
Q^2=0.50 W=2.40	✓	✓
Q^2=2.1 W=2.95	✗	✓
Q^2=3.0 W=2.32	✗	✓
Q^2=3.0 W=3.14	✗	✓
Q^2=4.4 W=2.74	✗	✓
Q^2=5.5 W=3.02	✗	✓

Collaborators welcome!