Beam Normal Single Spin Asymmetry in the N-to-Δ Transition

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for the Qweak Collaboration

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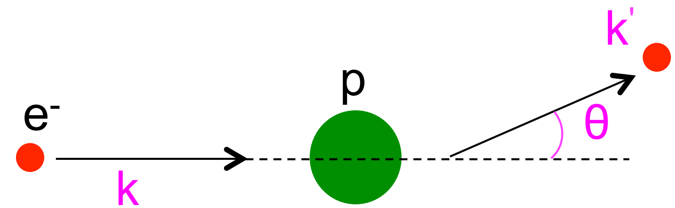
Jefferson Lab

HAMPTON UNIVERSITY

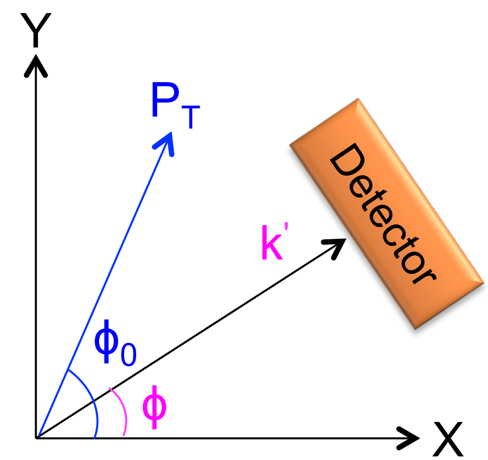
Beam Normal Single Spin Asymmetries (BNSSA) are generated when transversely polarized electrons (polarized perpendicular to their direction of motion) scatter from unpolarized targets.



Measured asymmetry

$$A_M(\phi) = \frac{\sigma\uparrow - \sigma\downarrow}{\sigma\uparrow + \sigma\downarrow} = -A_N \vec{P}_T . \hat{n} = A_N P_T \sin(\phi - \phi_0)$$

where $\hat{n} = \frac{\vec{k} \times \vec{k}'}{|\vec{k} \times \vec{k}'|}$, $\vec{P}_T$ is transverse polarization and A_N is BNSSA

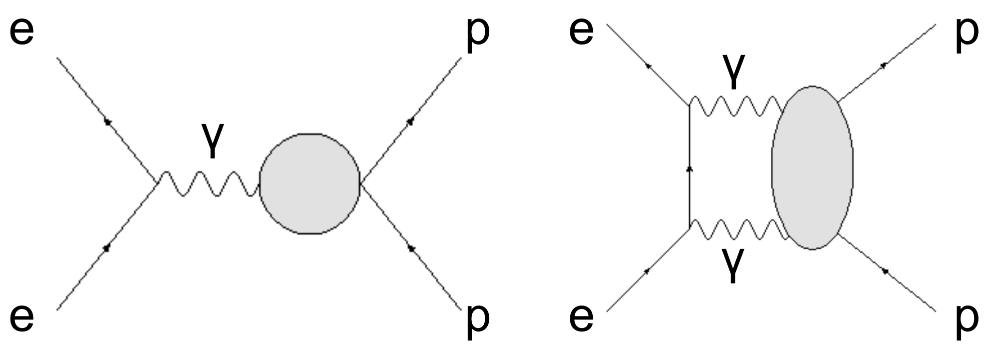


A_N is parity conserving and has a small azimuthal dependence.

Beam Normal Single Spin Asymmetry

$$A_N = \frac{2T_{1\gamma} \times \mathrm{Im}\, T_{2\gamma}}{|T_{1\gamma}|}$$

$T_{1\gamma}$ – amplitude for 1- photon exchange
$T_{2\gamma}$ – amplitude for 2- photon exchange

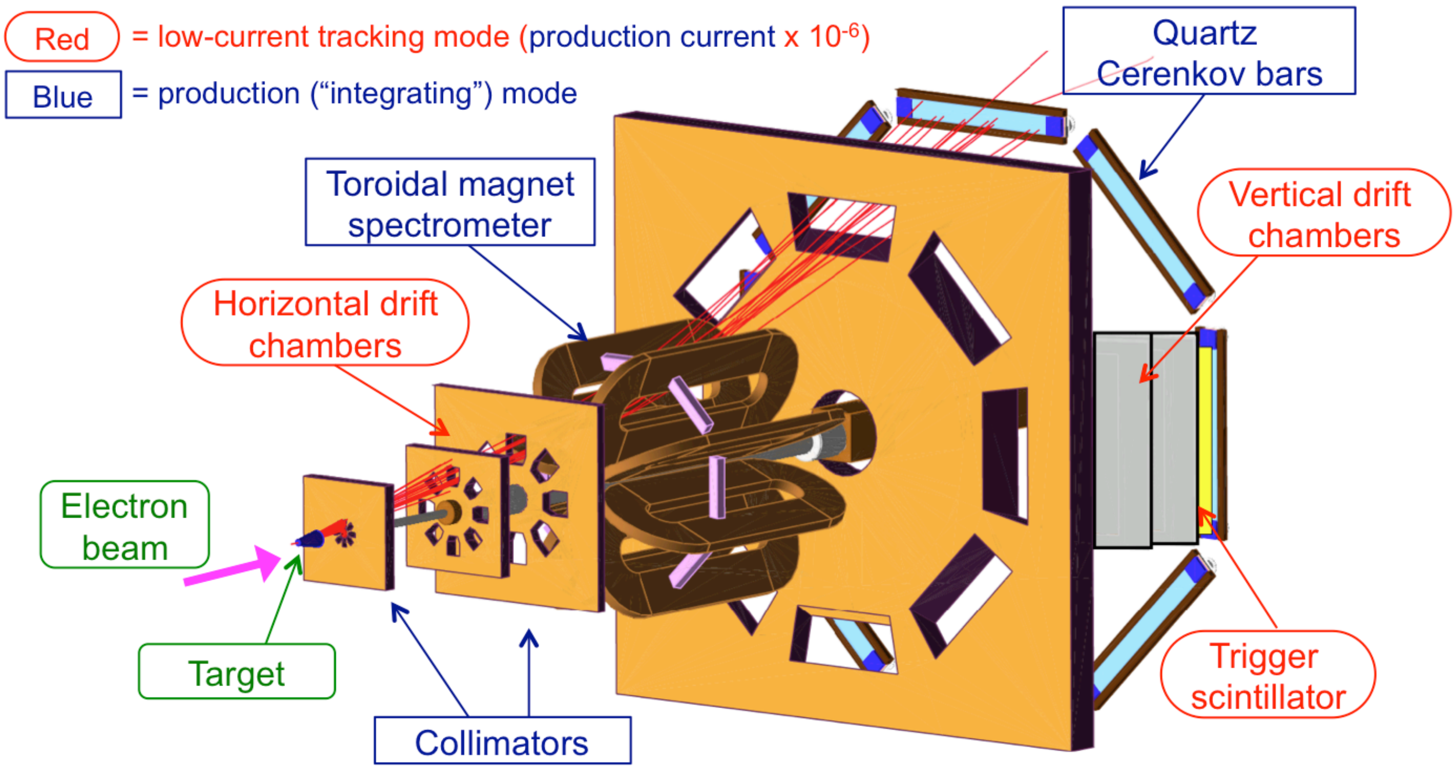


one photon exchange   two photon exchange

- A_N is proportional to two-photon exchange.
- Provides access to the imaginary part of the two-photon exchange amplitude.
- As part of a program of A_N background studies, we made the first measurement of A_N in the N-to-Δ transition using the Q-weak apparatus.

Q-weak Apparatus & Transverse Measurement

E_{beam} = 1.155 GeV
<Q[2]> ~ 0.025 $(GeV/c)^2$
<θ> ~ 7.9° ± 3°
ϕ coverage ~ 49% of 2π
Current = 180 μA
Polarization = 89%
Target = 34.4 cm LH_2
Cryopower = 2.5 kW
Luminosity $2\times10^{39} s^{-1} cm^{-2}$



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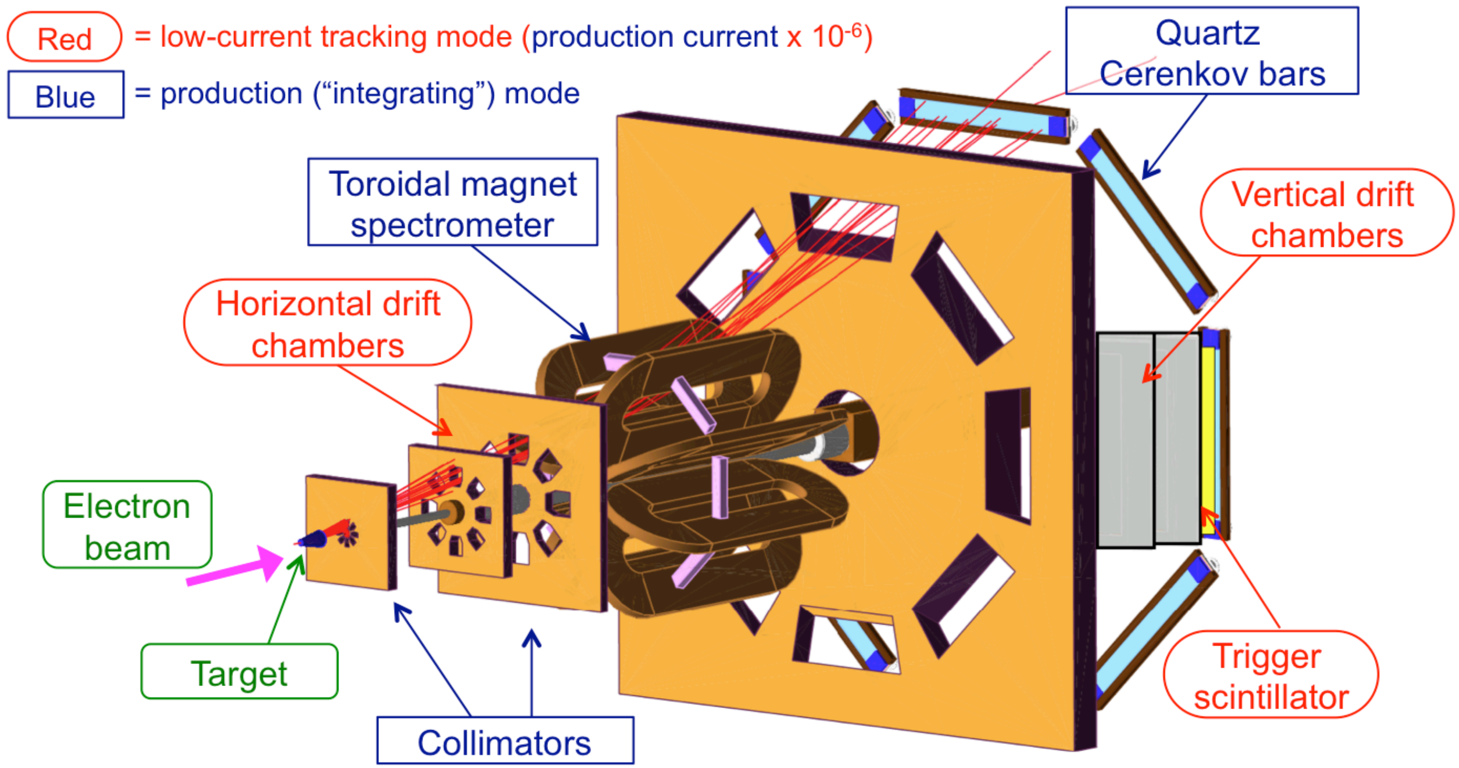
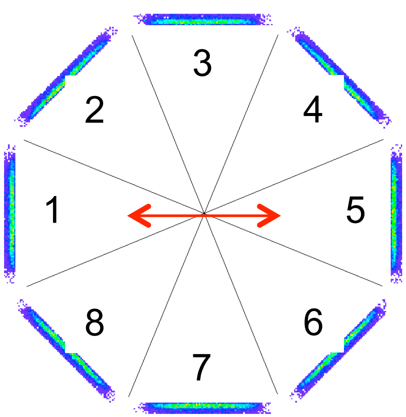
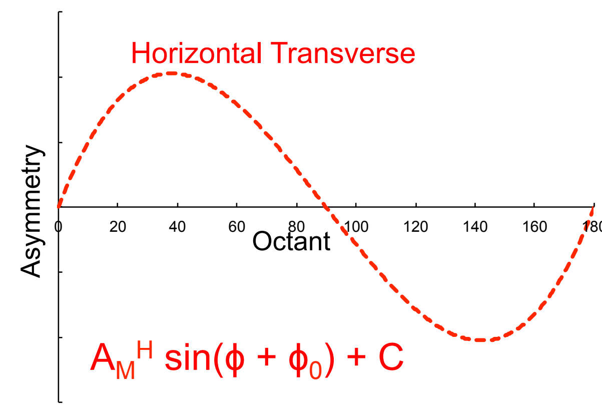




ϕ ➔ (octant # − 1) x 45^o

Fit regressed main detector asymmetries in the 8 octants using a fit.

A_M = magnitude of A_N
ϕ_0 = phase offset of ϕ
C = A_{PV} + background



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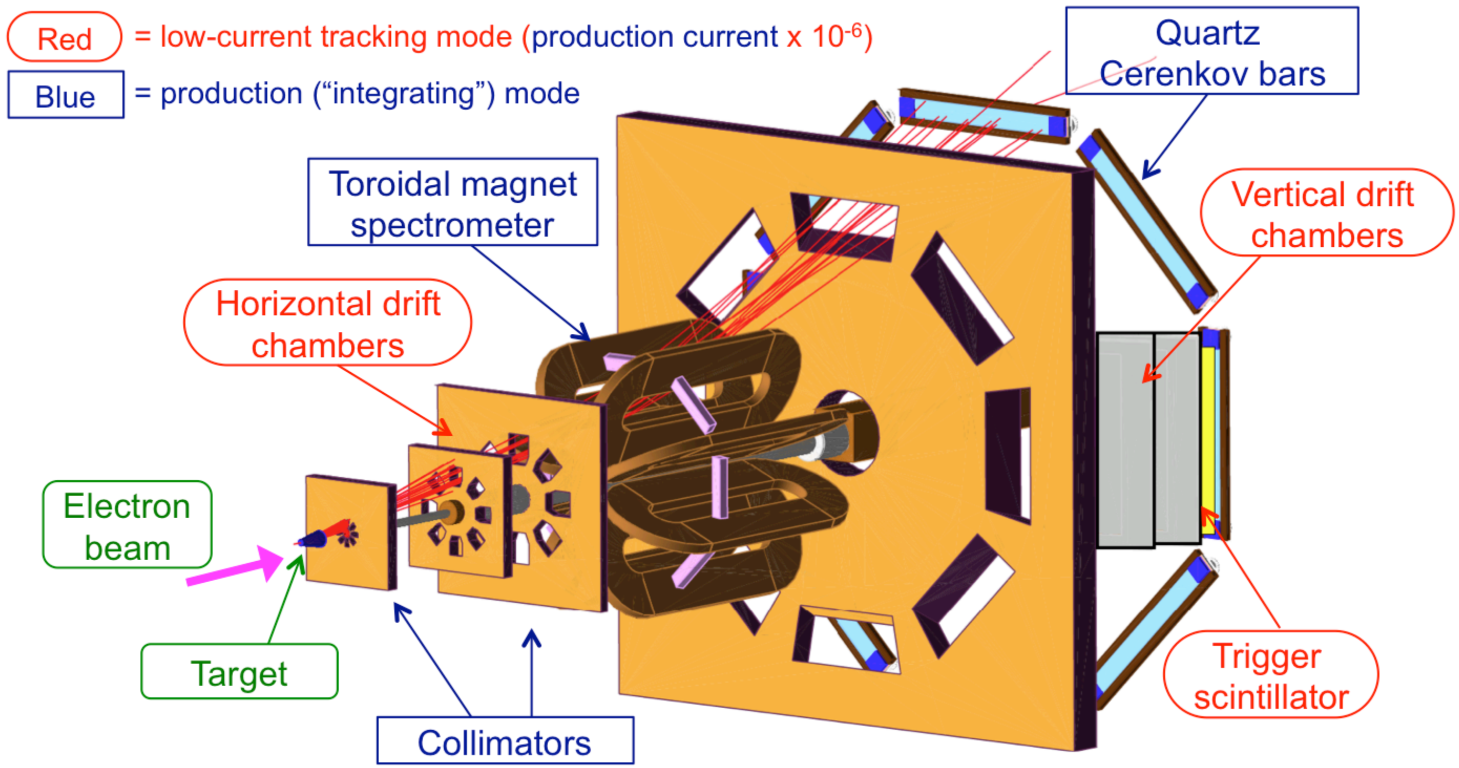

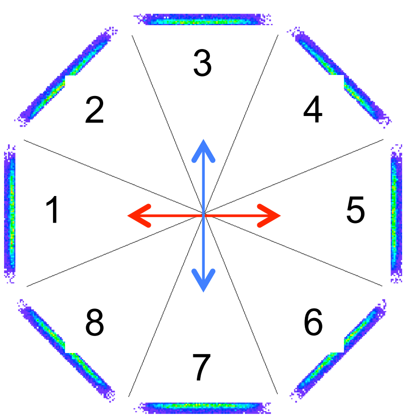

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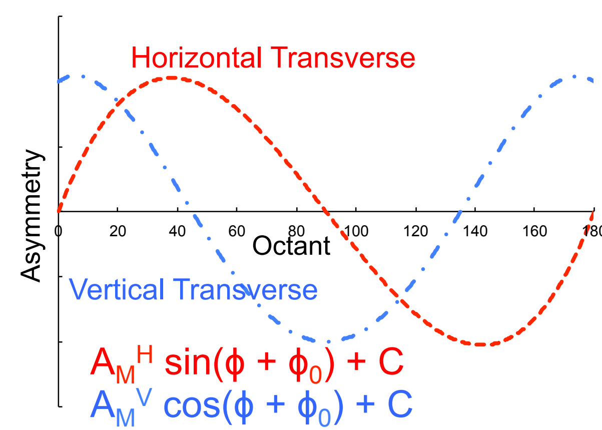
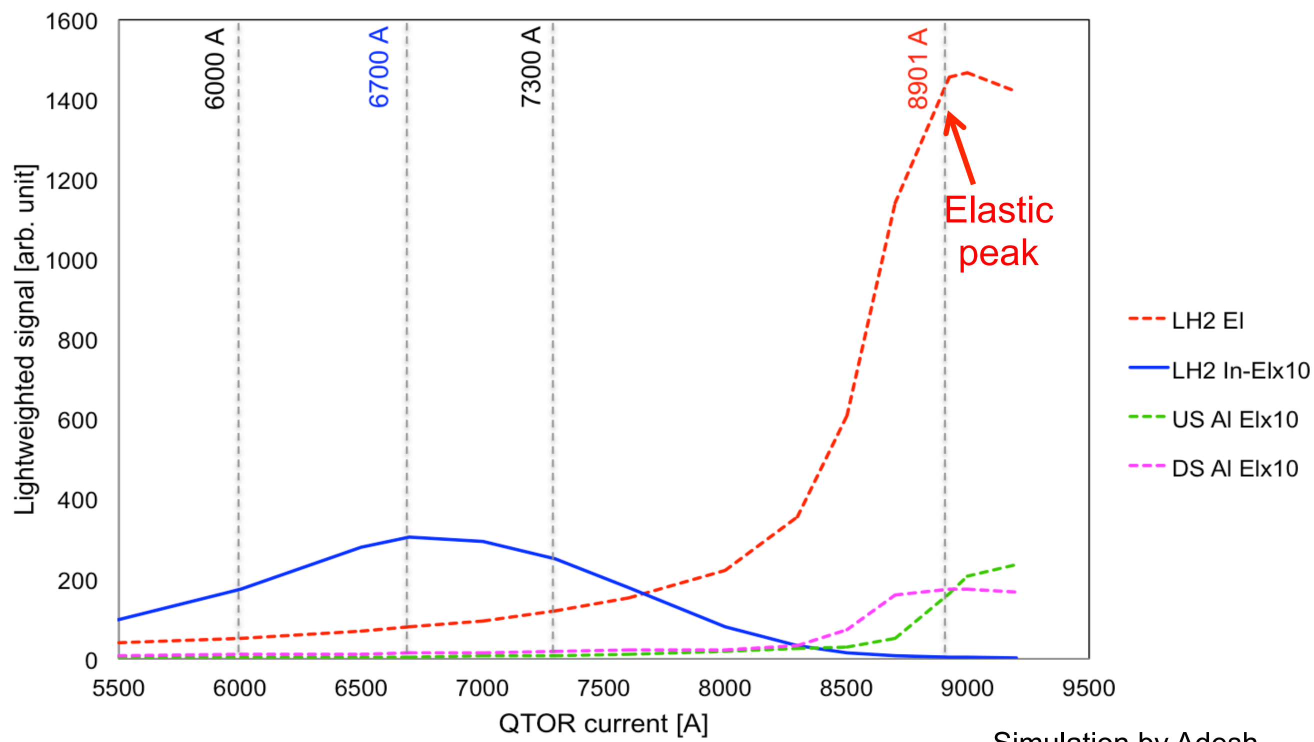


1.155 GeV Transverse Data Set



Simulation by Adesh Subedi using Geant-III

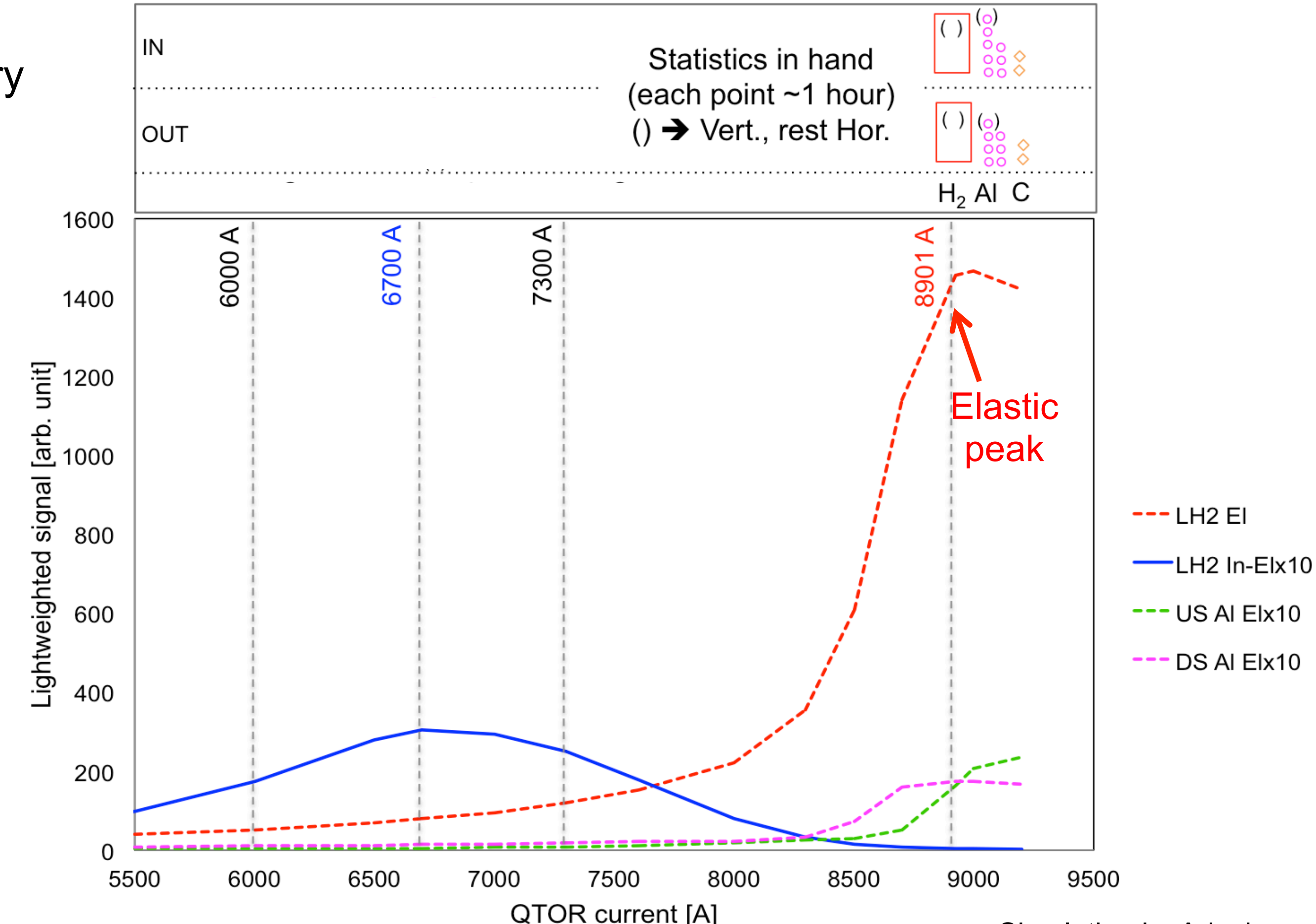
1.155 GeV Transverse Data Set

Data on 3 types of targets

- Liquid Hydrogen (primary target)
- Aluminum (to constrain target window background)
- Carbon (to help understand elastic and inelastic BNSSA from nuclei)

Two polarization configurations needed to check the symmetry of the main detector system.

- Vertical transverse polarization
- Horizontal transverse polarization



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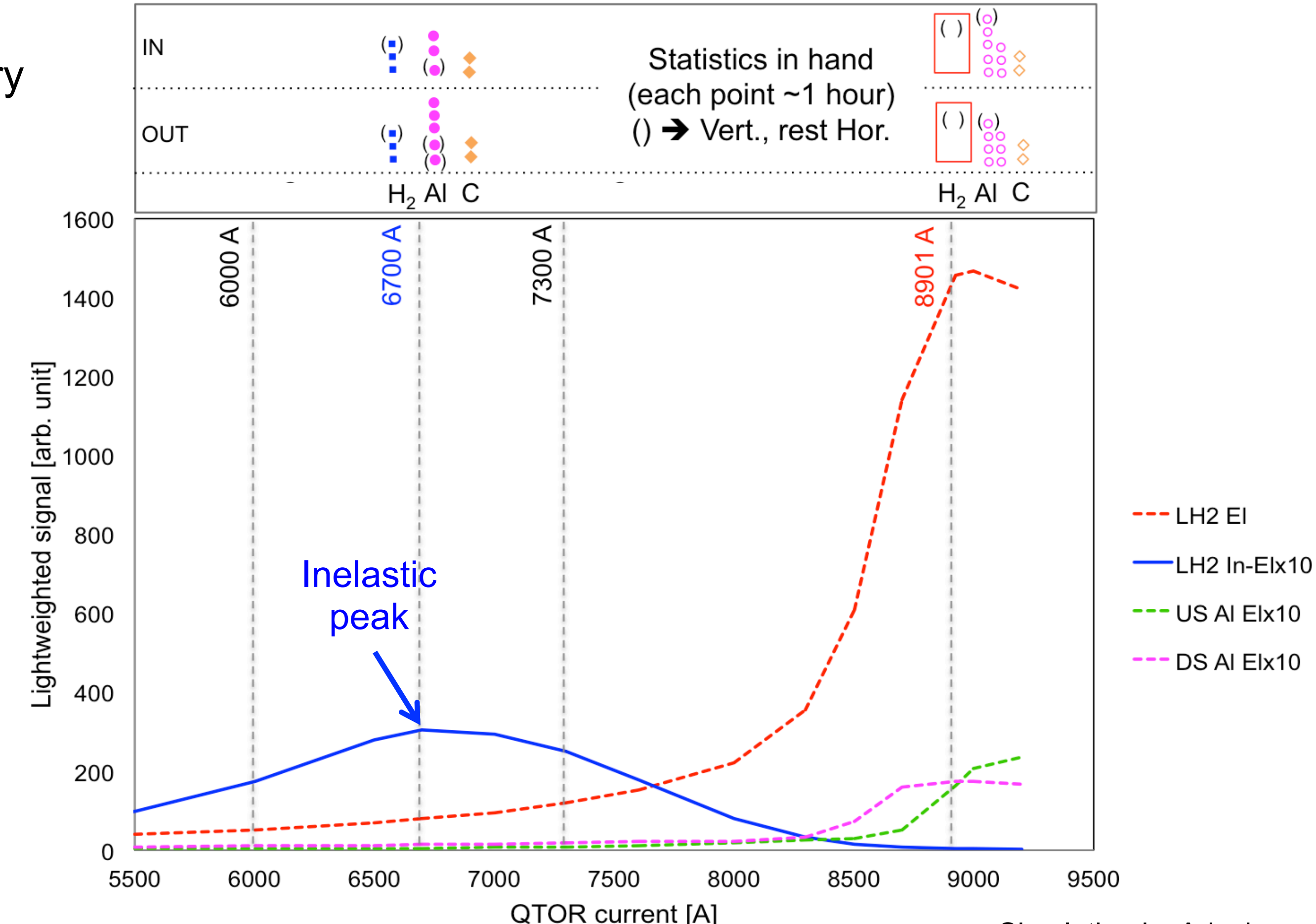

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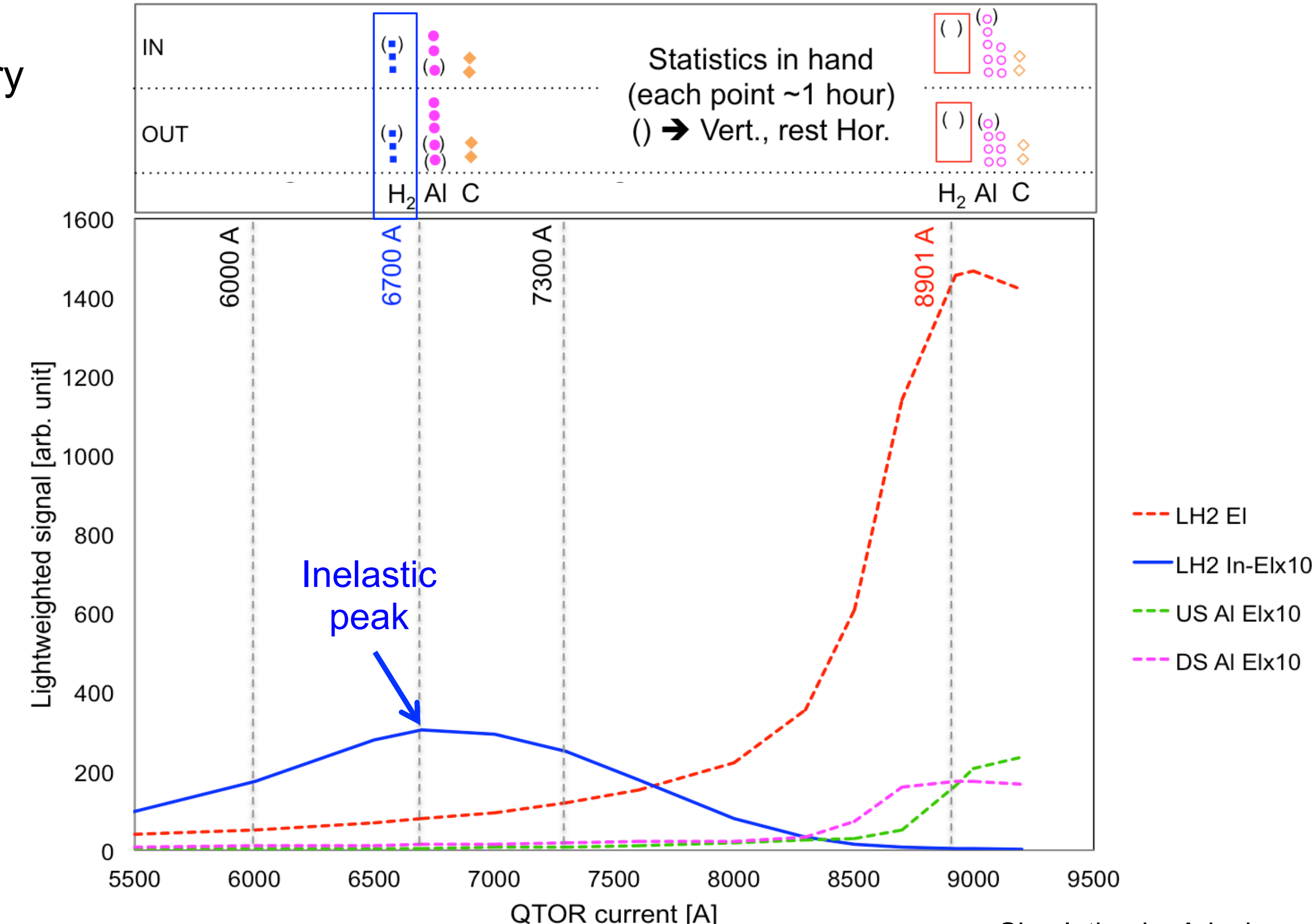

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This talk will focus on hydrogen data in the N-to-Δ transition

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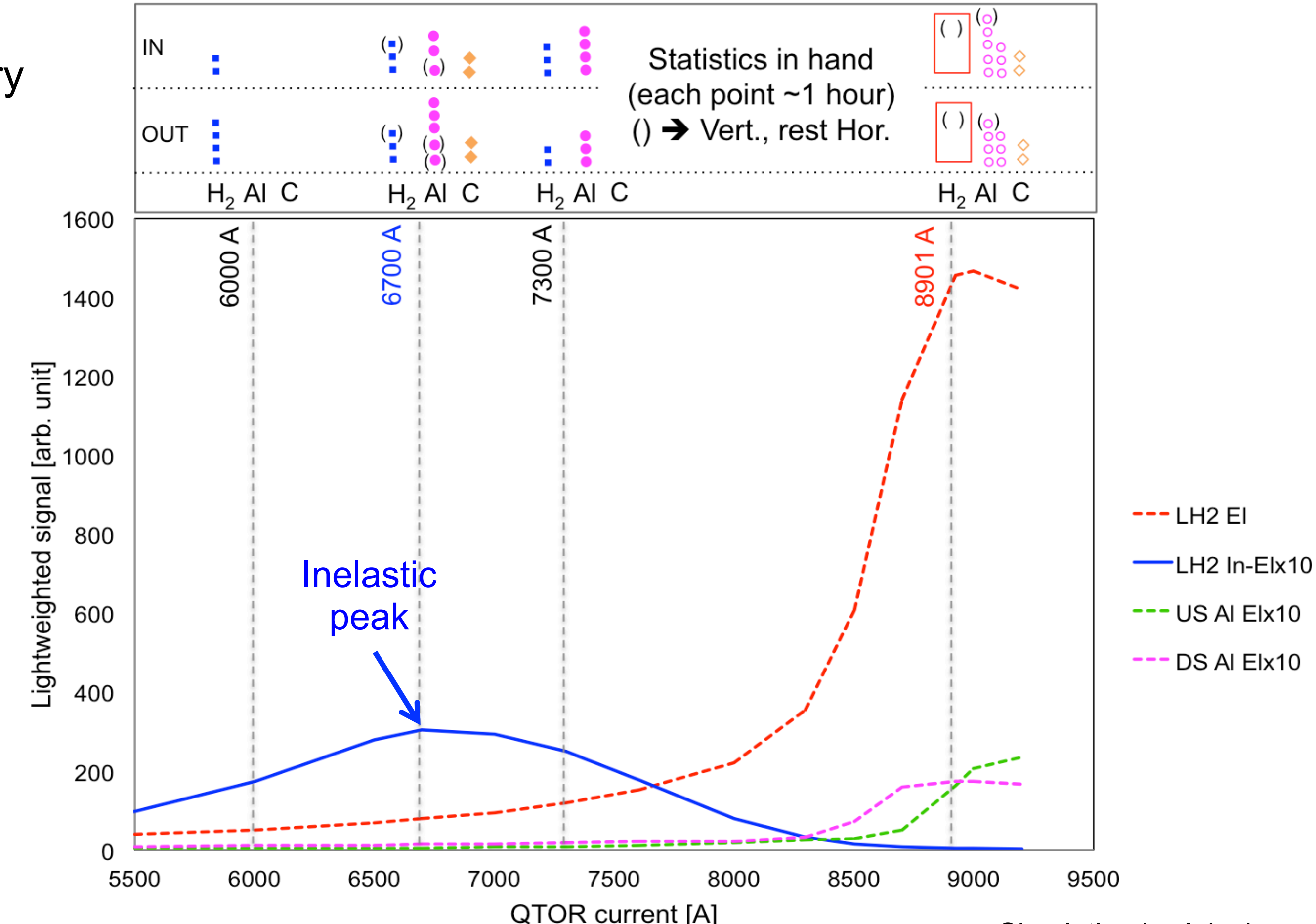
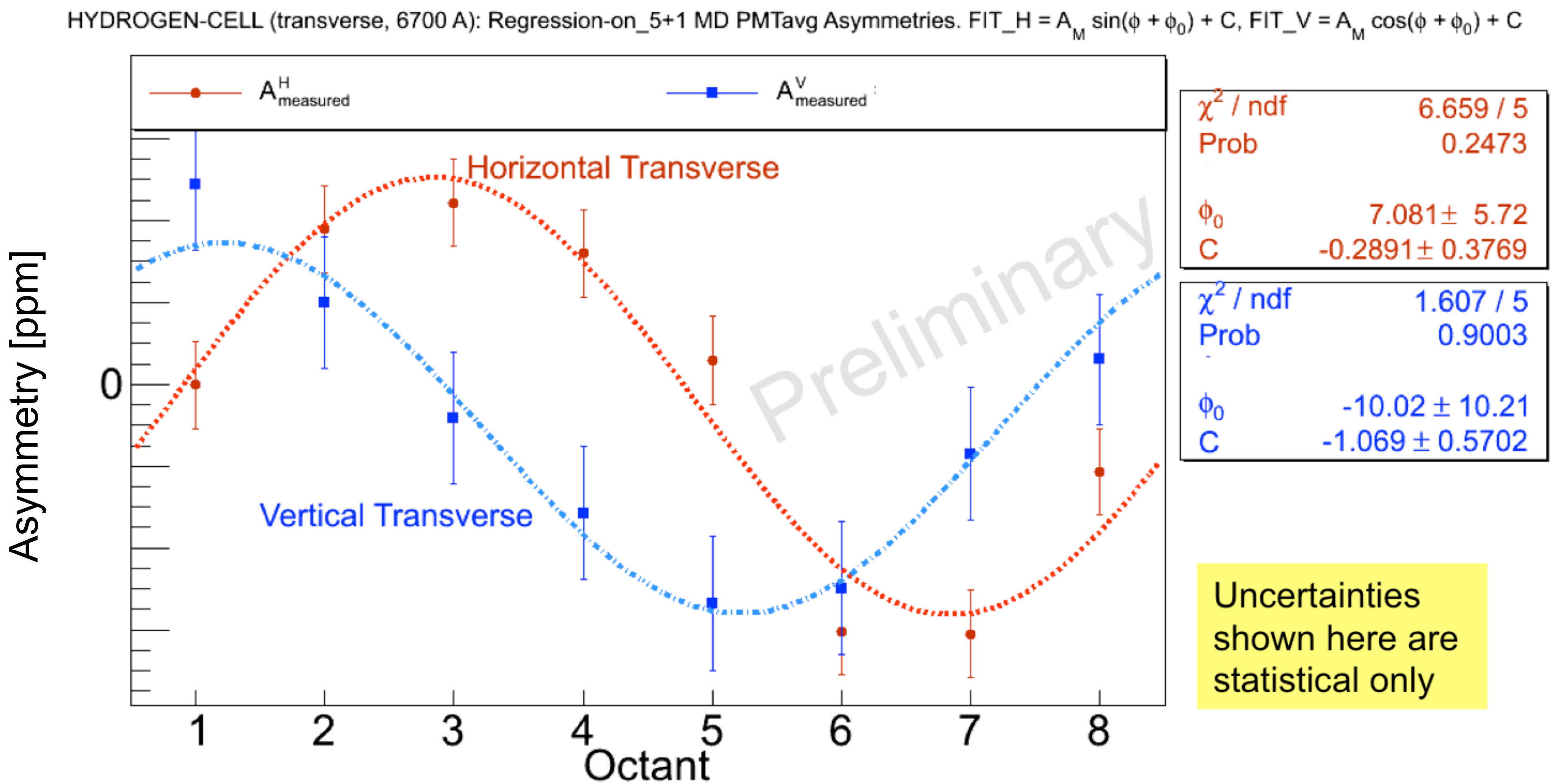


Simulation by Adesh Subedi using Geant-III

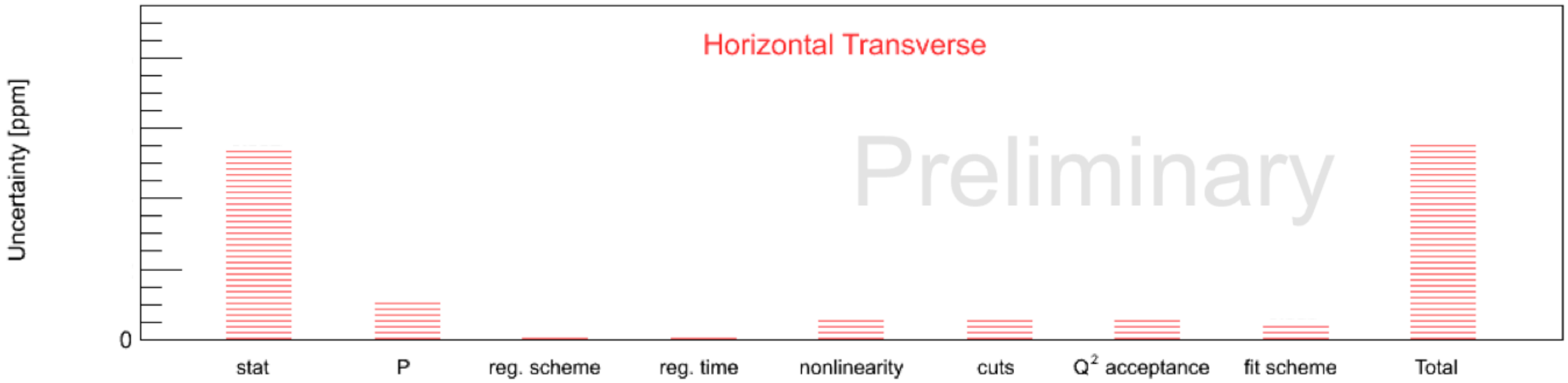
Data on both side of the inelastic peak were taken to improve simulation.

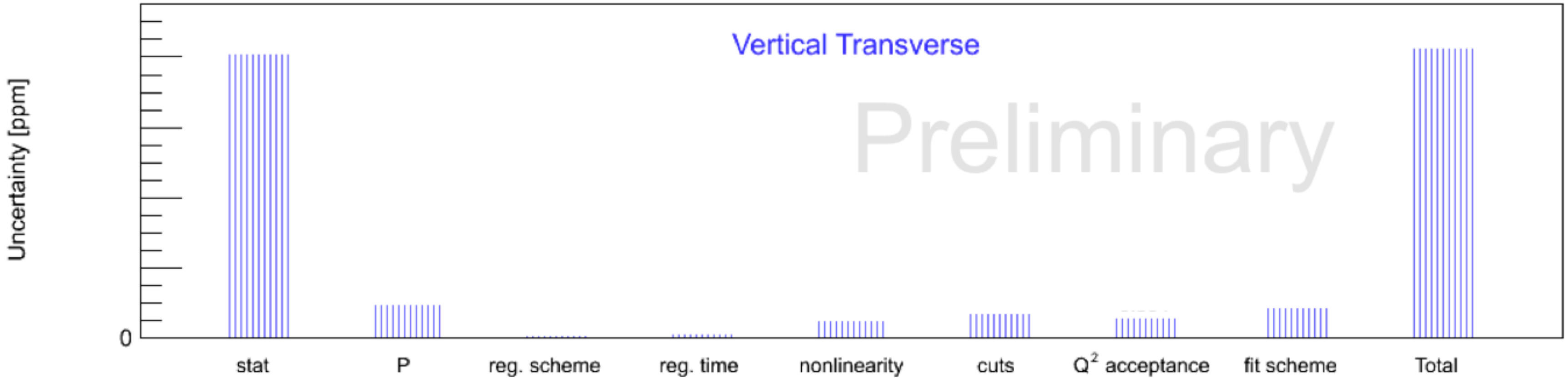
Raw Transverse Asymmetries (A_M^{in}) on LH_2

- ~ 9% statistical measurement of regressed transverse asymmetry in the N-to-Δ transition.
- Not corrected for backgrounds and polarization.
- ~ 90 degree phase offset seen between Vertical and Horizontal transverse fit (as expected).



Summary of Uncertainties for A_M^{in}





- The uncertainty is dominated by statistics.
- Next largest contribution comes from polarization.
- All other systematics are under control.

Extraction of Physics Asymmetry

Beam Normal Single Spin Asymmetry

$$A_N = R_{total}\left[\frac{\frac{A_M^{in}}{P} - \sum_{i=1}^{4} A_{bi} f_{bi}}{1 - \sum_{i=1}^{4} f_{bi}}\right]$$

A_{bi} = Background asymmetries

f_{bi} = dilution factors

Extraction of Physics Asymmetry

$$A_N = R_{RC} R_{Det} R_{Bin} R_{Q^2} \left[\frac{\frac{A_M^{in}}{P} - A_{b1} f_{b1} - A_{b2} f_{b2} - A_{b3} f_{b3} - A_{b4} f_{b4}}{1 - f_{b1} - f_{b2} - f_{b3} - f_{b4}} \right]$$

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Aluminum target windows:	A_{b1}	f_{b1}
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Elastics:	A_{b4}	f_{b4}

Multiplicative Corrections:

Radiative correction	R_{RC}
Detector bias	R_{Det}
Eective kinematics correction	R_{Bin}
Q^2 calibration	R_{Q2}

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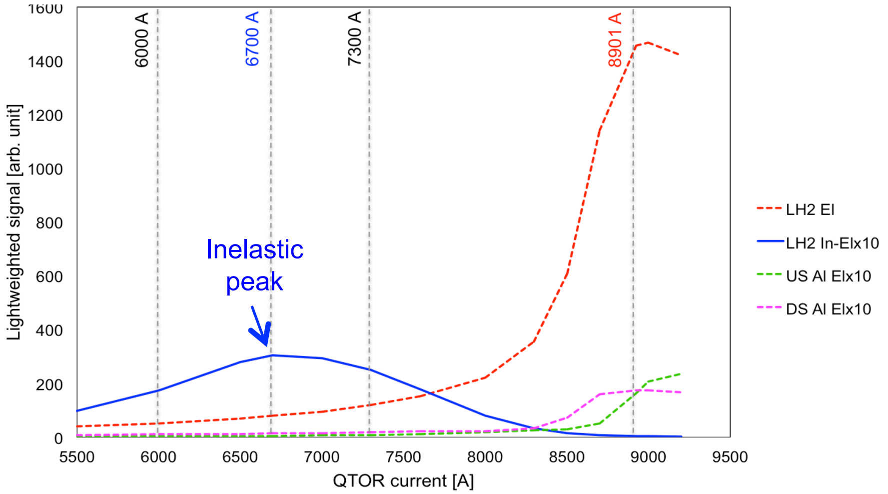


Physics asymmetry is highly diluted by the elastic radiative tail.
Careful study is ongoing.

Summary

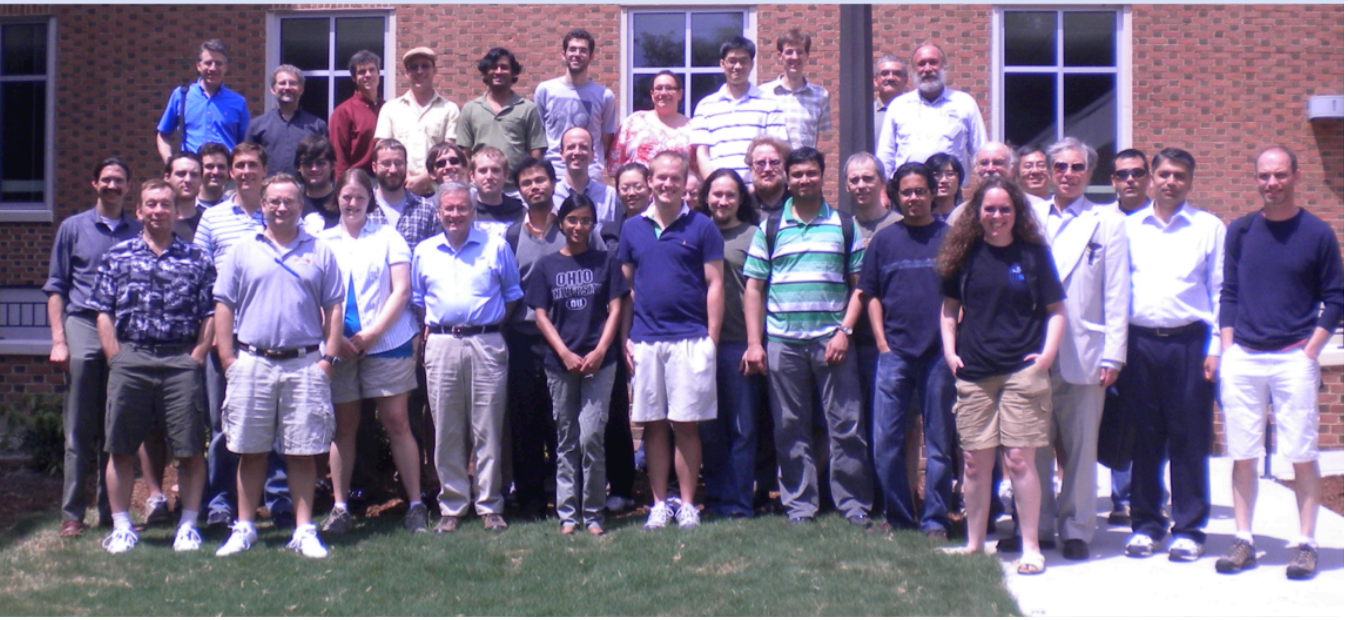
- As part of Q-weak background studies, we made the first measurement of A_N in the N-to-Δ transition on H_2.

- The uncertainty in the measured N-to-Δ transverse asymmetry is dominated by statistics. Other large uncertainties come from beam polarization and elastic dilution.

To Do:

- Quantify impact of these results on the parity violating N-to-Δ measurement and talk to theoretician for model calculation.

The Q-weak Collaboration



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[4] Massachusetts Institute of Technology
[5] Thomas Jefferson National Accelerator Facility
[6] Ohio University
[7] Christopher Newport University
[8] University of Manitoba,
[9] University of Virginia
[10] TRIUMF
[11] Hampton University
[12] Mississippi State University
[13] Virginia Polytechnic Institute & State University
[14] Southern University at New Orleans
[15] Idaho State University
[16] Louisiana Tech University
[17] University of Connecticut
[18] University of Northern British Columbia
[19] University of Winnipeg
[20] George Washington University
[21] University of New Hampshire
[22] Hendrix College, Conway
[23] University of Adelaide

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[1]Spokespersons [2]Project Manager Grad Students

95 collaborators 23 grad students
10 post docs 23 institutions

Backup Slides

$$A_N = R_{RC} R_{Det} R_{Bin} R_{Q^2} \left[\frac{\frac{A_M^{in}}{P} - A_{b1} f_{b1} - A_{b2} f_{b2} - A_{b3} f_{b3} - A_{b4} f_{b4}}{1 - f_{b1} - f_{b2} - f_{b3} - f_{b4}} \right]$$

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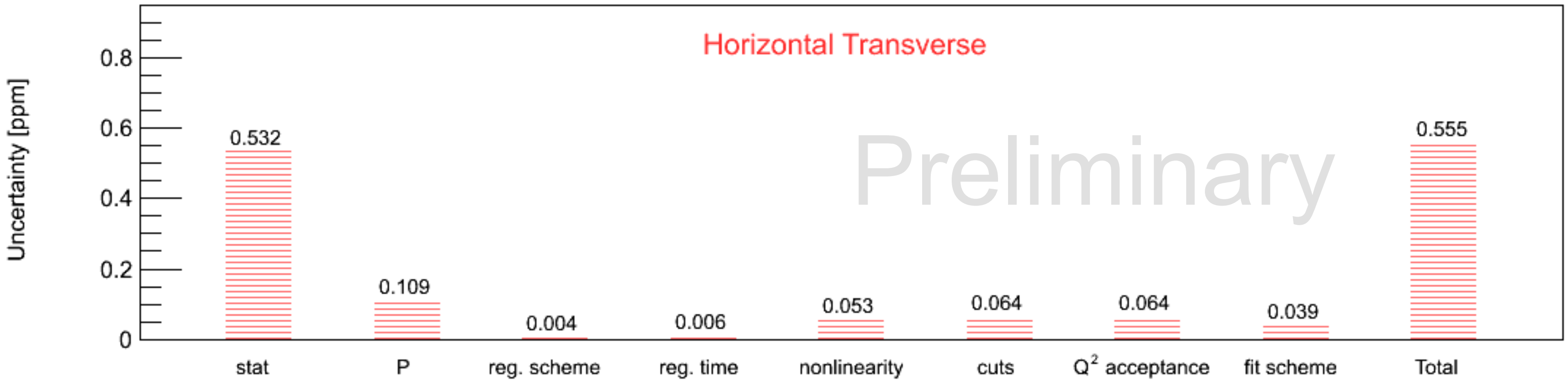

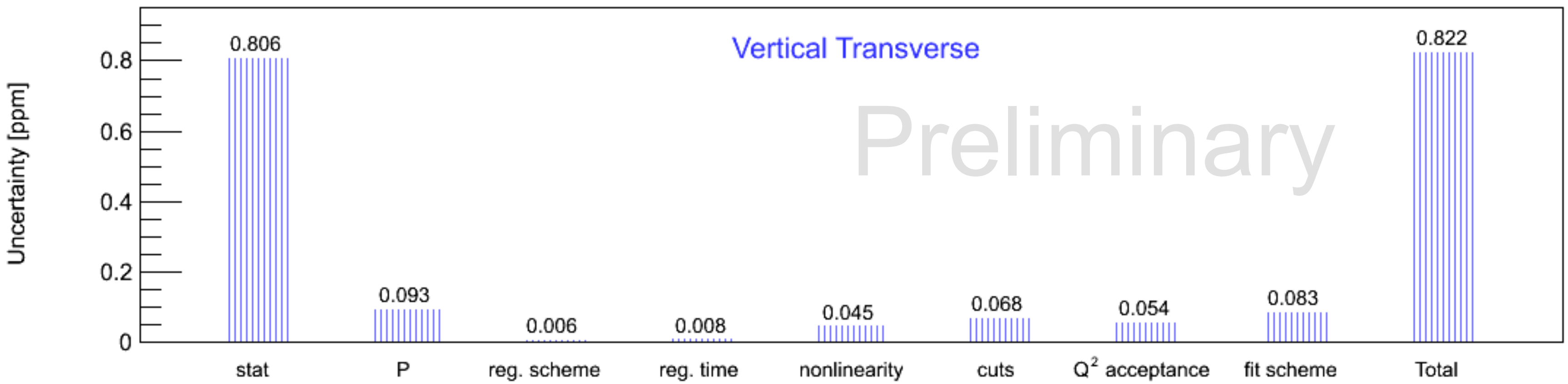

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Aluminum target windows:	$A_{b1} = 8.432 \pm 0.985$	ppm	$f_{b1} = 0.033 \pm 0.002$	$c_{b1} = 0.278$	DocDB 1819
Beamline scattering:	$A_{b2} = 2.229 \pm 6.843$	ppm	$f_{b2} = 0.018 \pm 0.001$	$c_{b2} = 0.040$	Elog 782, 784
Other neutral bkg:	$A_{b3} = 0.000 \pm 0.200$	ppm	$f_{b3} = 0.024 \pm 0.010$	$c_{b3} = 0.000$	Elog 714, DocDB 1549
Elastics:	$A_{b4} = -5.305 \pm 0.166$	ppm	$f_{b4} = 0.701 \pm 0.035$	$c_{b4} = -3.719$	Elog 837, DocDB 1601

Preliminary

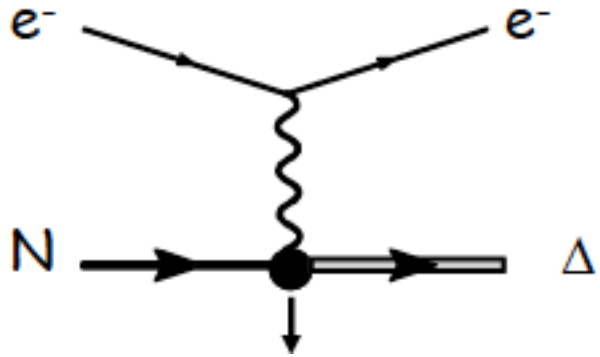
Multiplicative Corrections:

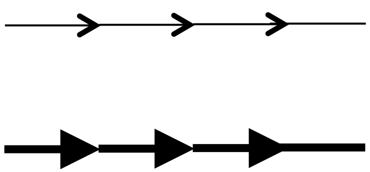
Radiative correction	$R_{RC} = 1.000 \pm 0.000$	Place holder
Detector bias	$R_{Det} = 1.000 \pm 0.000$	Place holder
Eective kinematics correction	$R_{Bin} = 1.000 \pm 0.000$	Place holder
Q^2 calibration	$R_{Q2} = 1.000 \pm 0.000$	Place holder

Extracted physics asymmetry $A_N = 41.05 \pm 7.90$ ppm.

title

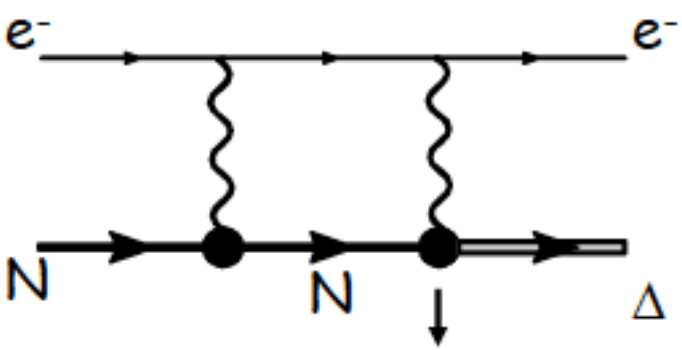
1γ exchange:



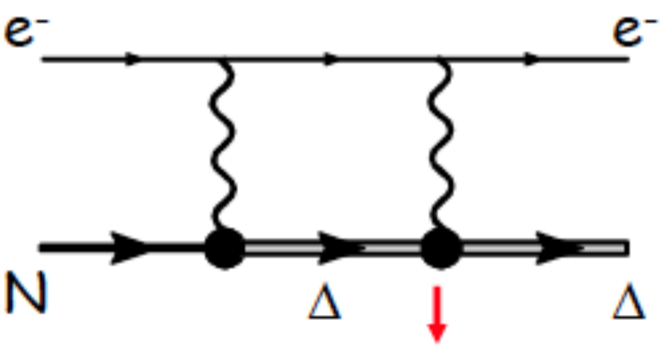


γ*NΔ form factors

2γ exchange:



γ*NΔ form factors

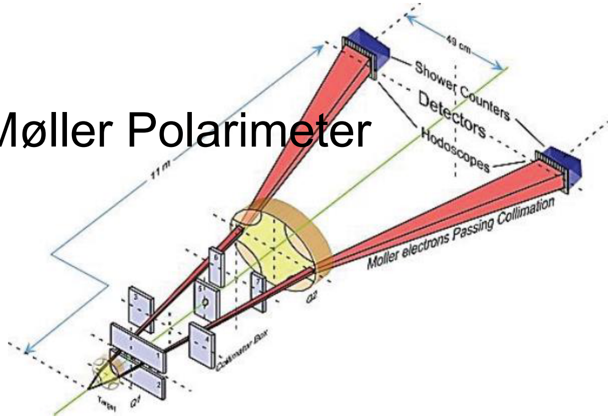


γ*ΔΔ form factors

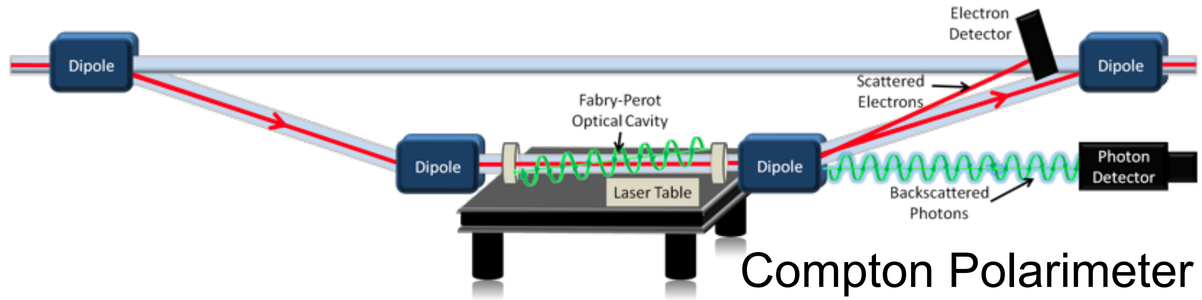
title

Polarimetry

Two independent polarimeters were used to measure beam polarization:



Møller Polarimeter

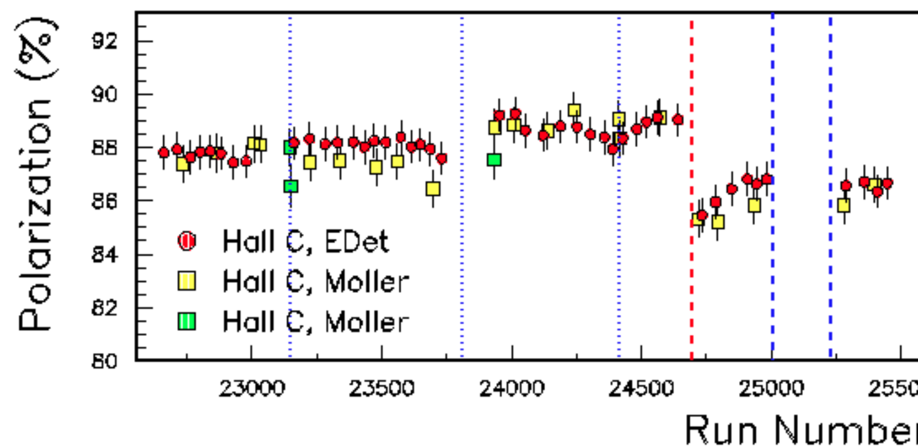


Compton Polarimeter

- existing Hall C Møller polarimeter to measure absolute beam polarization to <1% at low beam currents.
- New Compton polarimeter is used to provide continuous, nondestructive measurement of beam polarization at nominal experiment beam current.

A typical measured polarization is shown in the figure.

Measured beam polarization during commissioning period using Moller polarimeter is ~ 89 ± 2 % (Compton results during commissioning was not available)



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Elastics:	A_{b4}	f_{b4}	c_{b4}	

Preliminary

Asymmetry from this analysis shown at the beginning of the talk

Elastic dilution is used for Al. target windows correction – J. Magee. (Inelastic dilution for Al. target window is similar as elastic – K. Myers thesis p.122). Need an update.

Extraction of Physics Asymmetry

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Preliminary estimation using Mark. D and Kent's method for 25% paper. Assumed 10 times larger background for inelastic compare to elastic. Error bars are also blown up by factor of 10 to give a conservative estimate. Will update soon.

Measured for inelastic beamline background – J. Leacock thesis p. 169)

Extraction of Physics Asymmetry

$$A^{in}_{PHYS} = R_{RC}R_{Det}R_{Bin}R_{Q^2}\left[\frac{\frac{A^{in}_M}{P} - A_{b1}f_{b1} - A_{b2}f_{b2} - A_{b3}f_{b3} - A_{b4}f_{b4}}{1 - f_{b1} - f_{b2} - f_{b3} - f_{b4}}\right]$$

Background Asymmetries, Dilutions and Corrections:

Aluminum target windows:	A_{b1}	f_{b1}	c_{b1}	
Beamline scattering:	A_{b2}	f_{b2}	c_{b2}	
Other neutral bkg:	$A_{b3} = 0.000 \pm 0.200$ ppm	$f_{b3} = 0.024 \pm 0.010$	$c_{b3} = 0.000$	Elog 714, DocDB 1549
Elastics:	A_{b4}	f_{b4}	c_{b4}	

For now just taken from 25% LH_2 paper as place holder. Will update. Should not be a significant correction.

Using QTor transport channel analysis – Rakitha (Elog 714)

Extraction of Physics Asymmetry

$$A^{in}_{PHYS} = R_{RC} R_{Det} R_{Bin} R_{Q^2} \left[\frac{\frac{A^{in}_{M}}{P} - A_{b1} f_{b1} - A_{b2} f_{b2} - A_{b3} f_{b3} - A_{b4} f_{b4}}{1 - f_{b1} - f_{b2} - f_{b3} - f_{b4}} \right]$$

Background Asymmetries, Dilutions and Corrections:

Aluminum target windows:	A_{b1}	f_{b1}	c_{b1}	
Beamline scattering:	A_{b2}	f_{b2}	c_{b2}	
Other neutral bkg:	A_{b3}	f_{b3}	c_{b3}	
Elastics:	A_{b4} = -5.305 $\pm$ 0.166 ppm	f_{b4} = 0.701 $\pm$ 0.035	c_{b4} = -3.719	Elog 837, DocDB 1601

Elastic transverse asymmetry – Buddhini

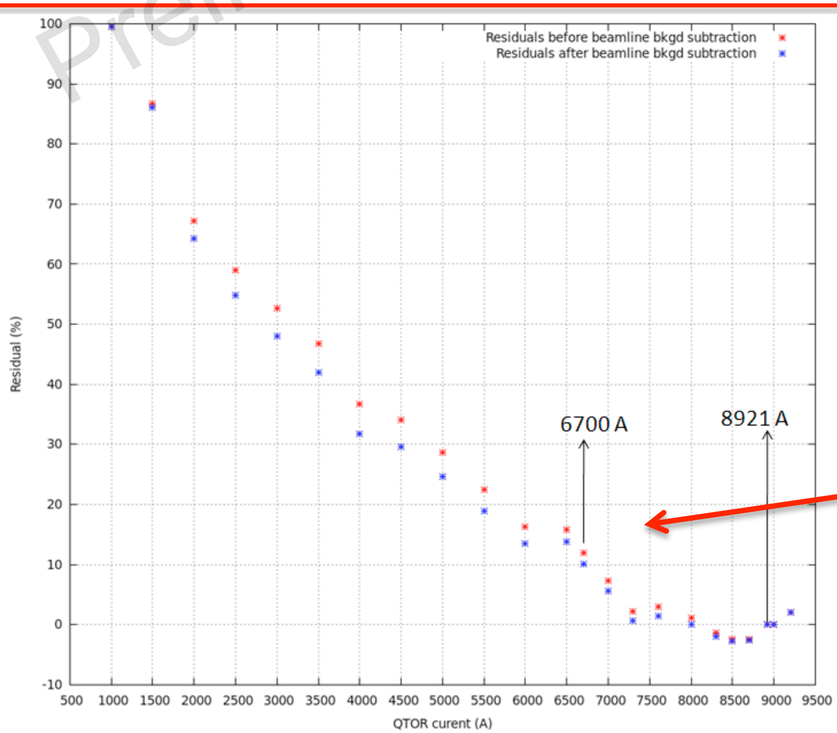
From geant-III simulation – Adesh Elog 837. Most important correction for this data set. This is a conservative estimate of dilution. Assumed ± 5.0% error on dilution due to 10.0% discrepancy between simulation and data. Need to update.

Extraction of Physics Asymmetry

$$A_{PHYS}^{in} = R_{RC} R_{Det} R_{Bin} R_{Q^2} \left[\frac{\frac{A_M^{in}}{P} - A_{b1}f_{b1} - A_{b2}f_{b2} - A_{b3}f_{b3} - A_{b4}f_{b4}}{1 - f_{b1} - f_{b2} - f_{b3} - f_{b4}} \right]$$

Background Asymmetries, Dilutions and Corrections:

Aluminum target windows:	A_{b1}	f_{b1}	c_{b1}	
Beamline scattering:	A_{b2}	f_{b2}	c_{b2}	
Other neutral bkg:	A_{b3}	f_{b3}	c_{b3}	
Elastics:	A_{b4} = -5.305 ± 0.166 ppm	f_{b4} = 0.701 ± 0.035	c_{b4} = -3.719	Elog 837, DocDB 1601



From geant-III simulation – Adesh Elog 837. Most important correction for this data set. This is a conservative estimate of dilution. Assumed ± 5.0% error on dilution due to 10.0% discrepancy between simulation and data. Need to update.