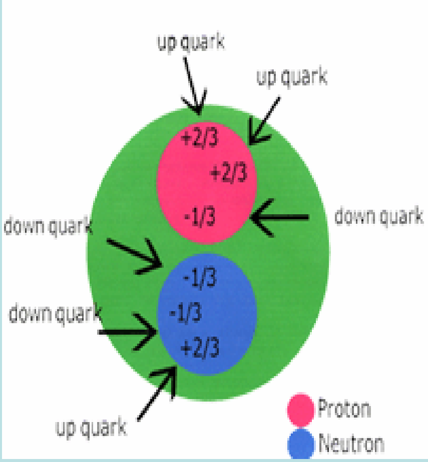
Study of the GDH Sum Rule on ^{3}He at HI γ S

- *Introduction*
- *Three-body Photodisintegration of ^{3}He @ HI γ S*
- *Preliminary Results from May 2008*
- *Future Plan*
- *Summary*

Haiyan Gao
TUNL and Duke University
Chiral Dynamics Workshop, Bern,
Switzerland,
July 9, 2009

No Stable Free Neutron Target



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- *Polarized deep inelastic scattering spin structure of neutron*
- *Spin-dependent quasielastic scattering from ^{3}He*

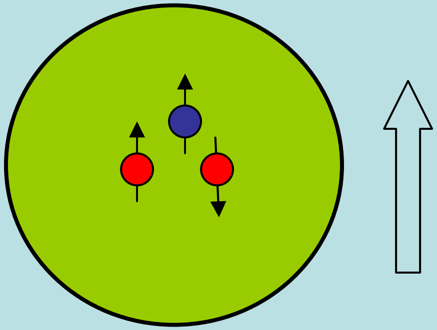
→ *neutron EM form factors*

Importance in testing state-of-the-arts Three-body calculations, EFT calculations
Excellent system to study three-body force effect (D. Phillips's talk)

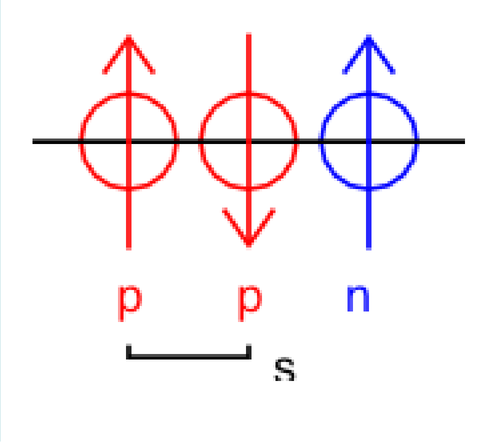
Compton Scattering →

Polarizabilities,…….

Polarized ^{3}He



About 88%



GDH sum rule

$$I^{GDH} = \int_{\nu_{thr}}^{\infty} \frac{d\nu}{\nu}\left[\sigma_N^P(\nu) - \sigma_N^A(\nu)\right] = \frac{4\pi^2\alpha}{M_N^2}\kappa_N^2 I$$

σ_N^P σ_N^A spin dependent total photon-absorption cross section

κ_N anomalous magnetic moment

Fundamental Interpretation: any particle with a nonzero anomalous magnetic moment has internal structure and therefore an excitation spectrum

- Based on general principles of physics: Lorentz and Gauge invariance, crossing symmetry, causality and unitarity
- First measurement on proton up to 800 MeV (Mainz) and up to 3 GeV (Bonn) agree with GDH with assumptions for contributions from un-measured regions (new measurements at Mainz).

P: target spin parallel to the photon spin

A: spins anti-parallel to the photon spin

Vince Sulkosky (Tuesday)

GDH Integral on ^{3}He

$$\int_{\nu_{thr}}^{\infty} GDH_{^3He} = \int_{\nu_{thr}}^{\nu_\pi} GDH_{^3He} + \int_{\nu_\pi}^{2-3GeV} GDH_{^3He} + \int_{2-3GeV}^{\infty} GDH_{^3He}$$

$496\,\mu b$ ^{3}He GDH Sum Rule

$217\,\mu b$??? HIγS @ DUKE

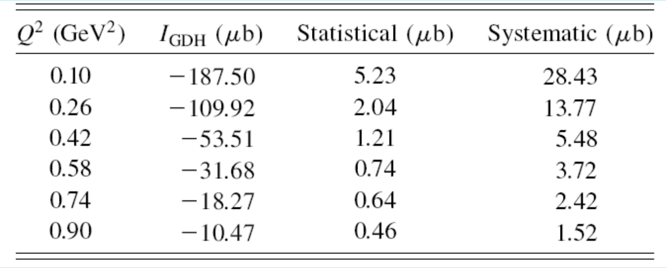
Extrapolated from low Q^2 ^{3}He GDH (E94-010) measurement @ JLab

M. Amarian, PRL 89, 242301(2002)

(**E97-110 much lower Q^2)**

Vince Sulkosky (Tuesday)

$\sim 247\,\mu b$



Q^2 (GeV^2)	I_{GDH} (μb)	Statistical (μb)	Systematic (μb)
0.10	−187.50	5.23	28.43
0.26	−109.92	2.04	13.77
0.42	−53.51	1.21	5.48
0.58	−31.68	0.74	3.72
0.74	−18.27	0.64	2.42
0.90	−10.47	0.46	1.52

$32\,\mu b$

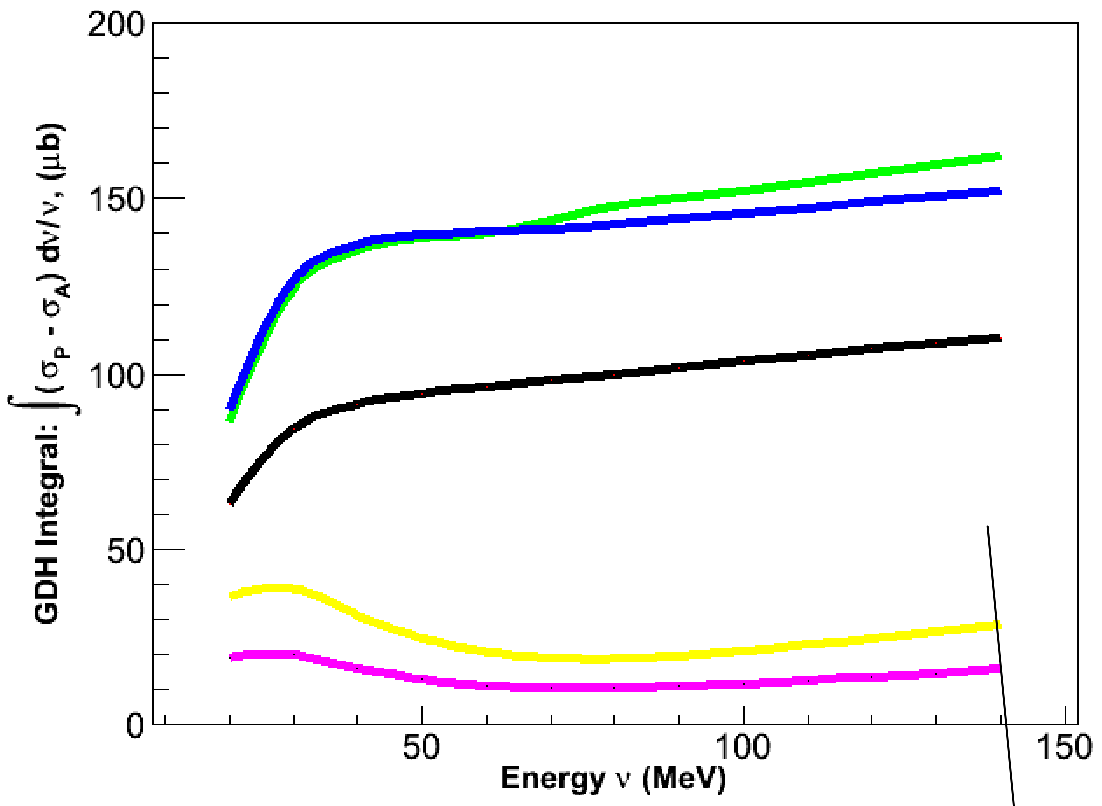
$$\int_{2-3GeV}^{\infty} GDH_{^3He} = P_n \times \int_{2-3GeV}^{\infty} GDH_n + 2 \times P_p \times \int_{2-3GeV}^{\infty} GDH_p$$
$$= 0.87 \times 35 + 2 \times (-0.027) \times (-26)$$

K. Slifer (next talk)

J. L. Friar et al. PRC 42, 2310 (1990)

N. Bianchi, et al. PLB 450, 439 (1999)

Few-body calculations of GDH integral up to ν_π



Color	Theories	GDH integral
Green	CDB+ Δ + Siegert RCO+ MEC(h.o.)	$162\mu b$
Blue	CDB+ Siegert including RCO+ MEC(h.o.)	$152\mu b$
Black	AV18+explicit MEC	$110\mu b$
Yellow	CD Bonn +Siegert +MEC(h.o.)	$28.7\mu b$
Magenta	AV18+implicit MEC via Siegert	$26.3\mu b$

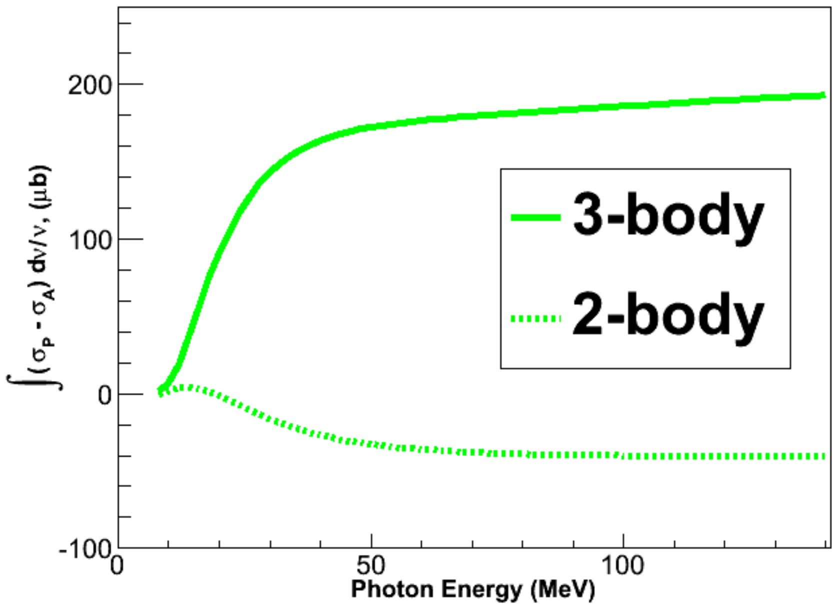
Deltuva, Fonseca and Sauer,
PRC71, 054005(2005), and private communications

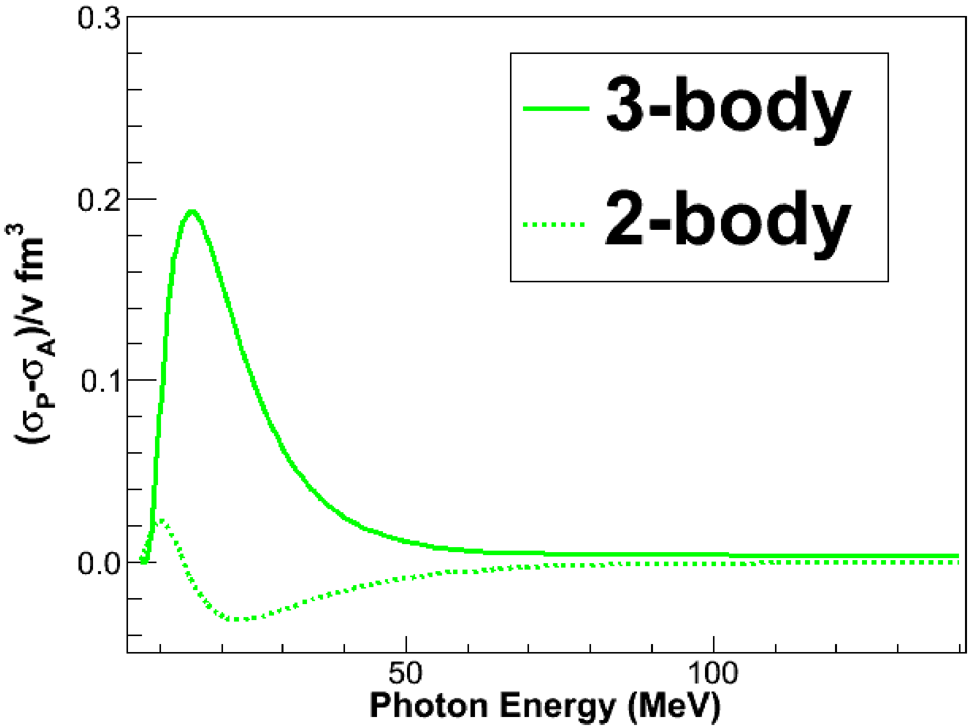
Skibinski, Golak et al. PRC72,
044002 (2005), and private communications

Calculations provided by Deltuva et al, Golak et al.

Compare to $217\mu b$???

GDH Integral and integrand: two-body and three-body





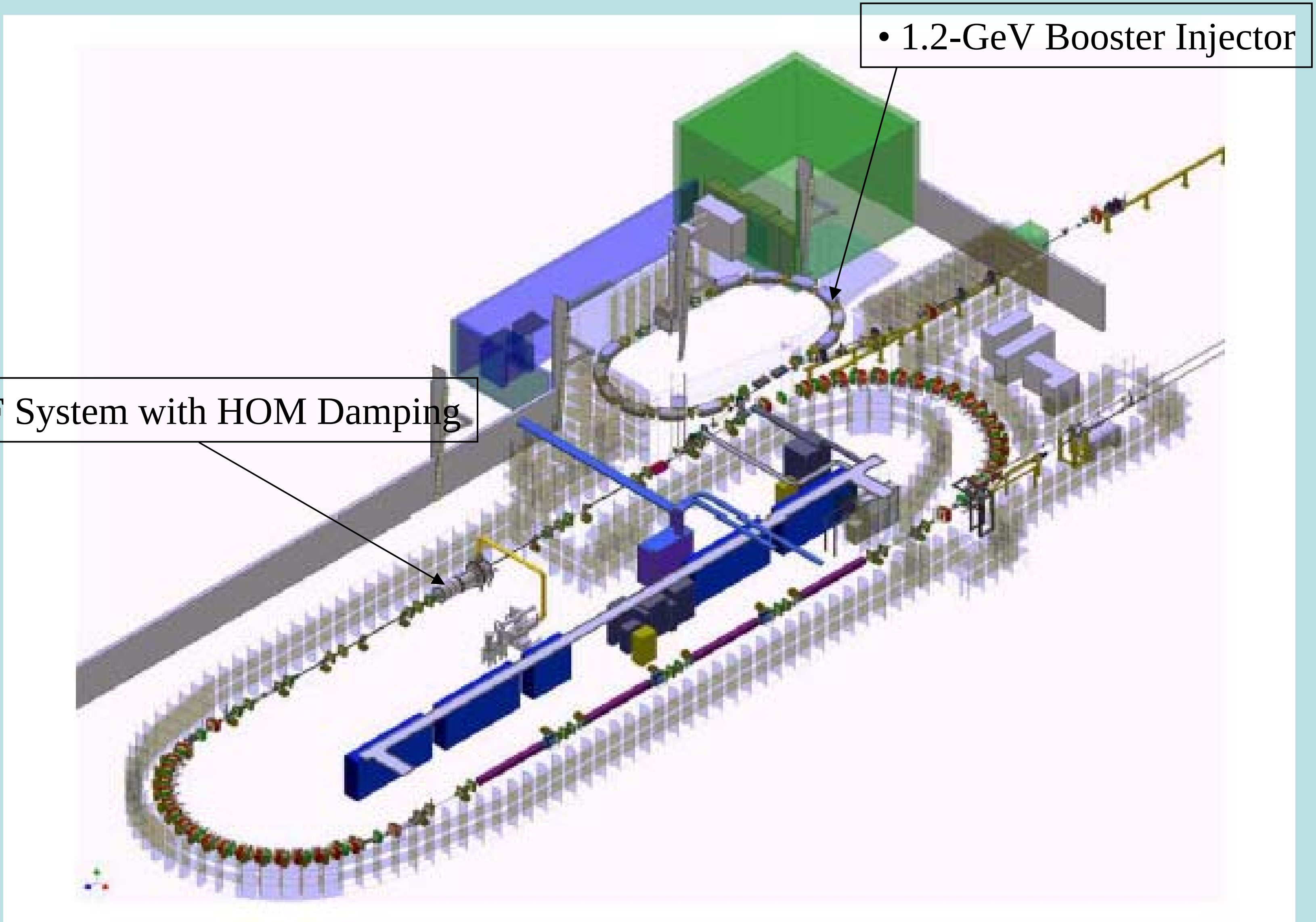
Calculation: Deltuva et al.
(see previous slide)

Highlights the importance of the
Three-body breakup channel

HIγS

- ***Nearly Mono-energetic γ-rays***
  - ***Tunable Energies***
  - ***Energy resolution selected by collimator size***
- ***Linearly (circularly) Polarized γ-rays***
- ***High Beam Intensities***
- ***Pulsed Beam***
  - ***TOF Techniques to reduce non-beam related backgrounds***

The Upgraded *HIγ*S Facility

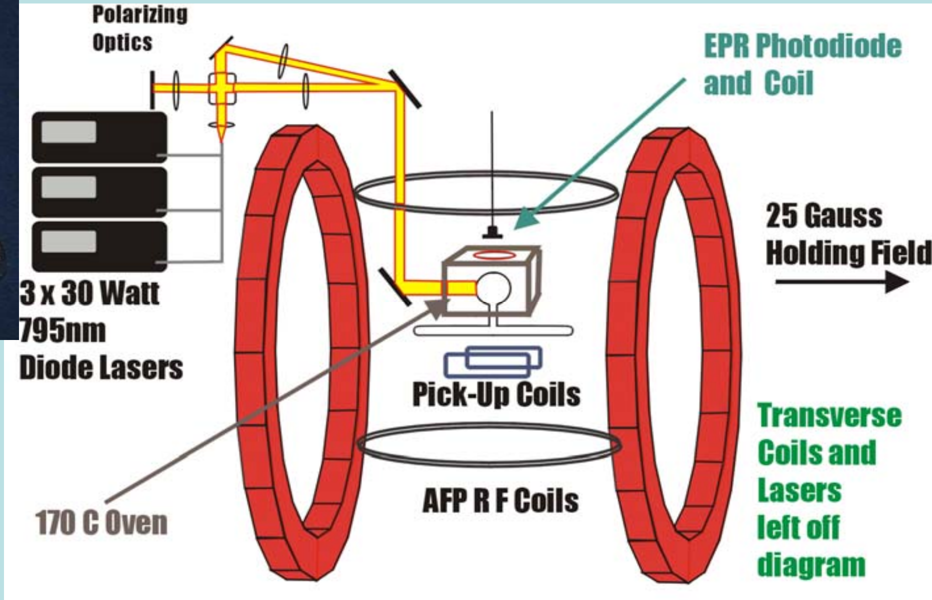


- 1.2-GeV Booster Injector

- RF System with HOM Damping

GDH with HIγS at the DFELL

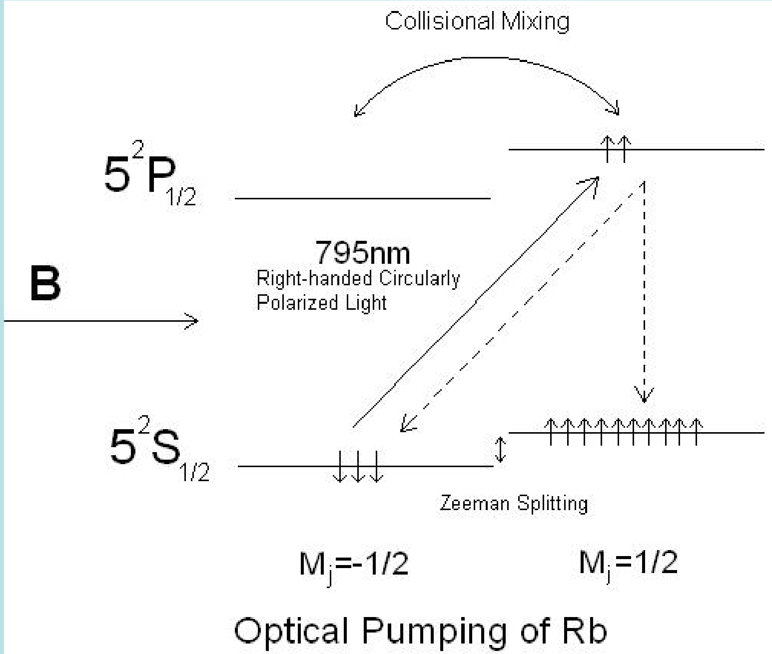
The HIGS facility along with a high pressure polarized ^{3}He target is an ideal place for this measurement.



Two-body breakup and three-body breakup measurements are needed
Three-body breakup dominates the integral at low energies

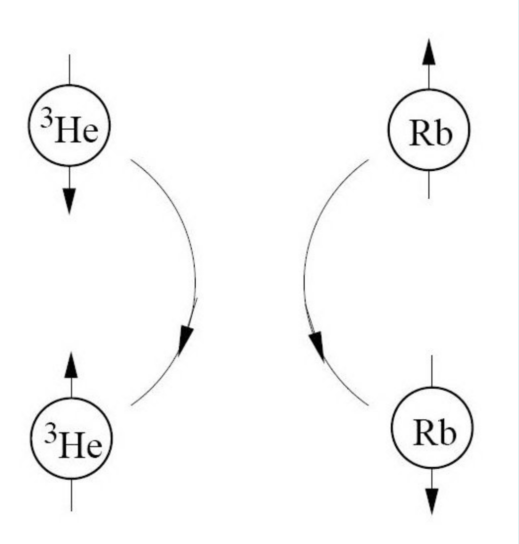
Spin exchange optical pumping

- Optical pumping[1]



Polarize Rb outer shell electron

- Spin exchange[2]



Spin exchange between
Rb electrons ←→ ^{3}He nuclei
Hyperfine

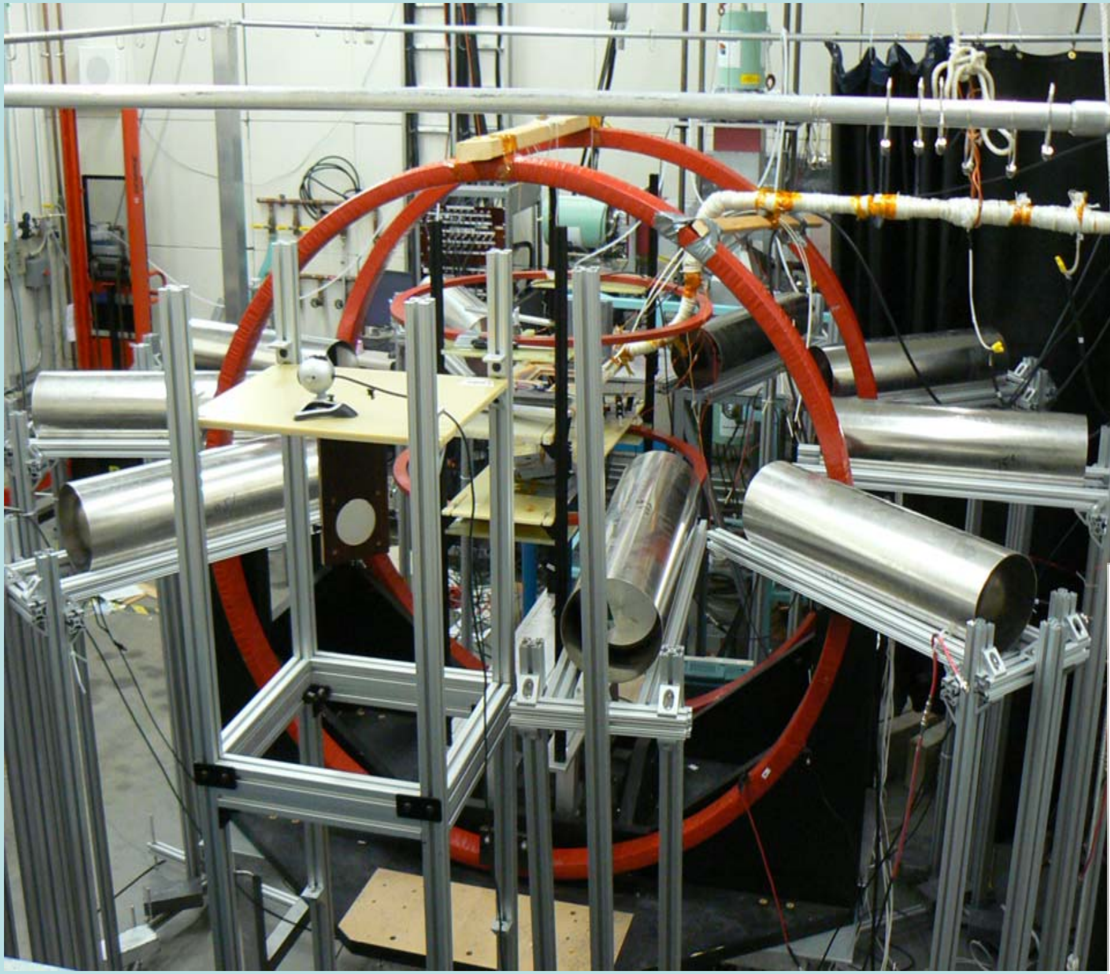
Spin exchange between (for Rb/K hybrid)
Rb electrons ←→ K atoms
K electrons ←→ 3He nuclei Hyperfine

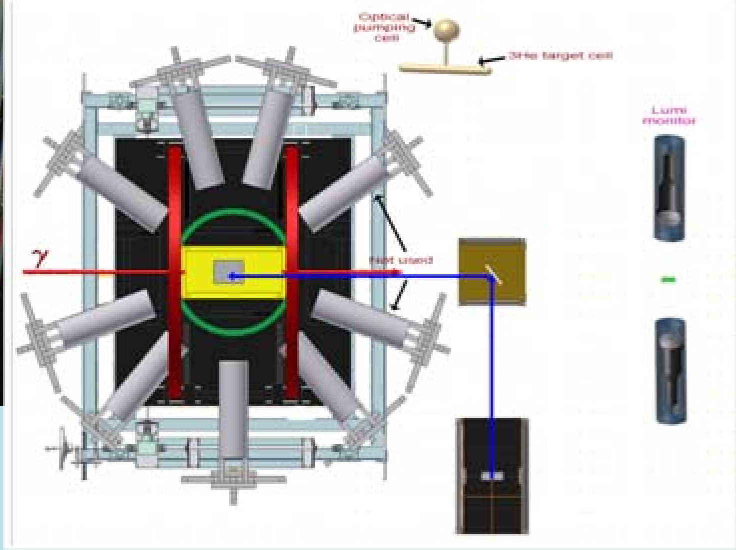
[1] W. Happer. Rev. Mod. Phys., 44:169, 1972.
[2] T. Walker and W. Happer. Rev. Mod. Phys., 69:629, 1997.

First Experiment@FEL, May 2008

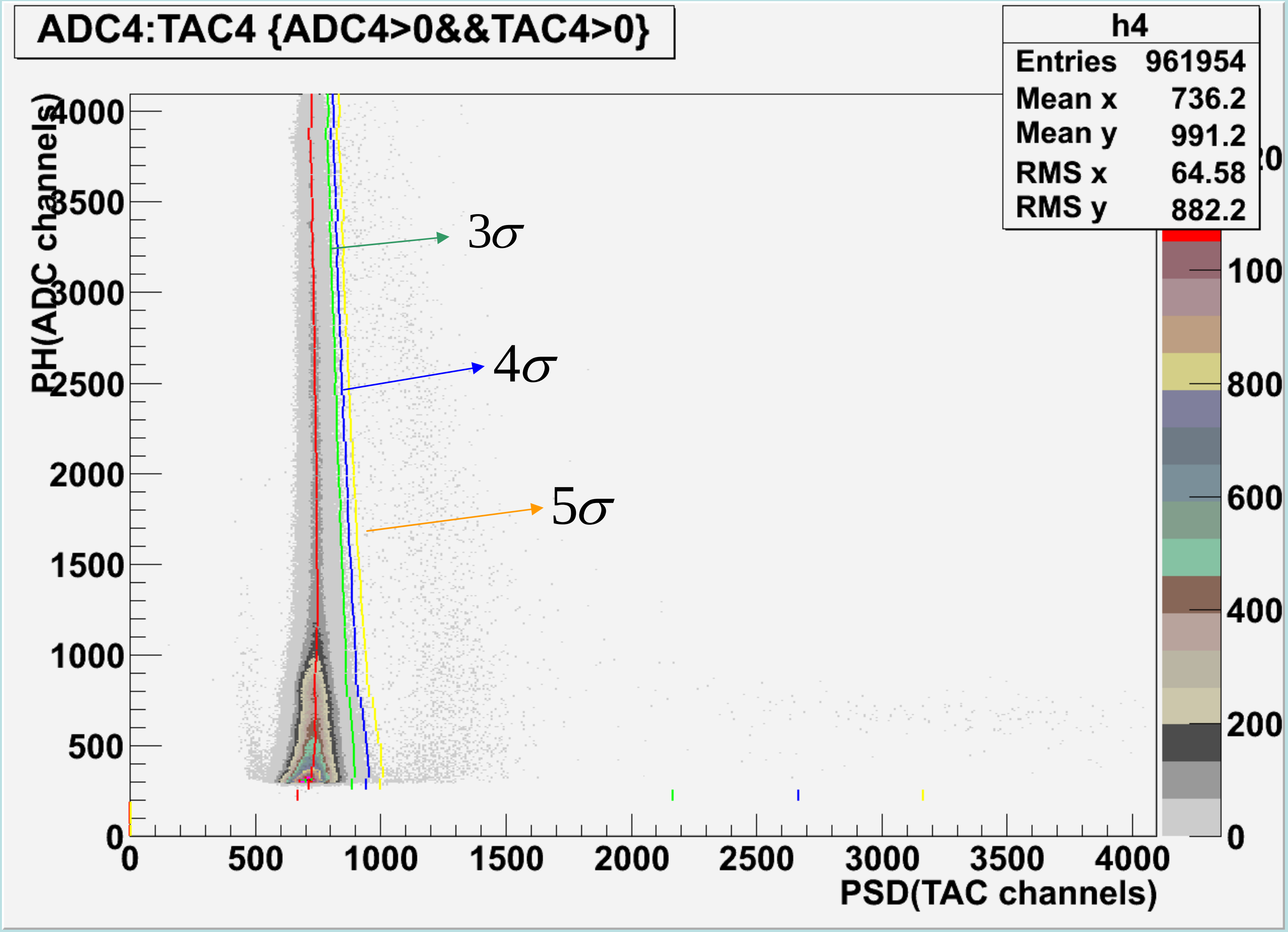
Detector Angles

20.0
35.0
50.0
75.0
90.0
105.0
130.0
145.0
160.0

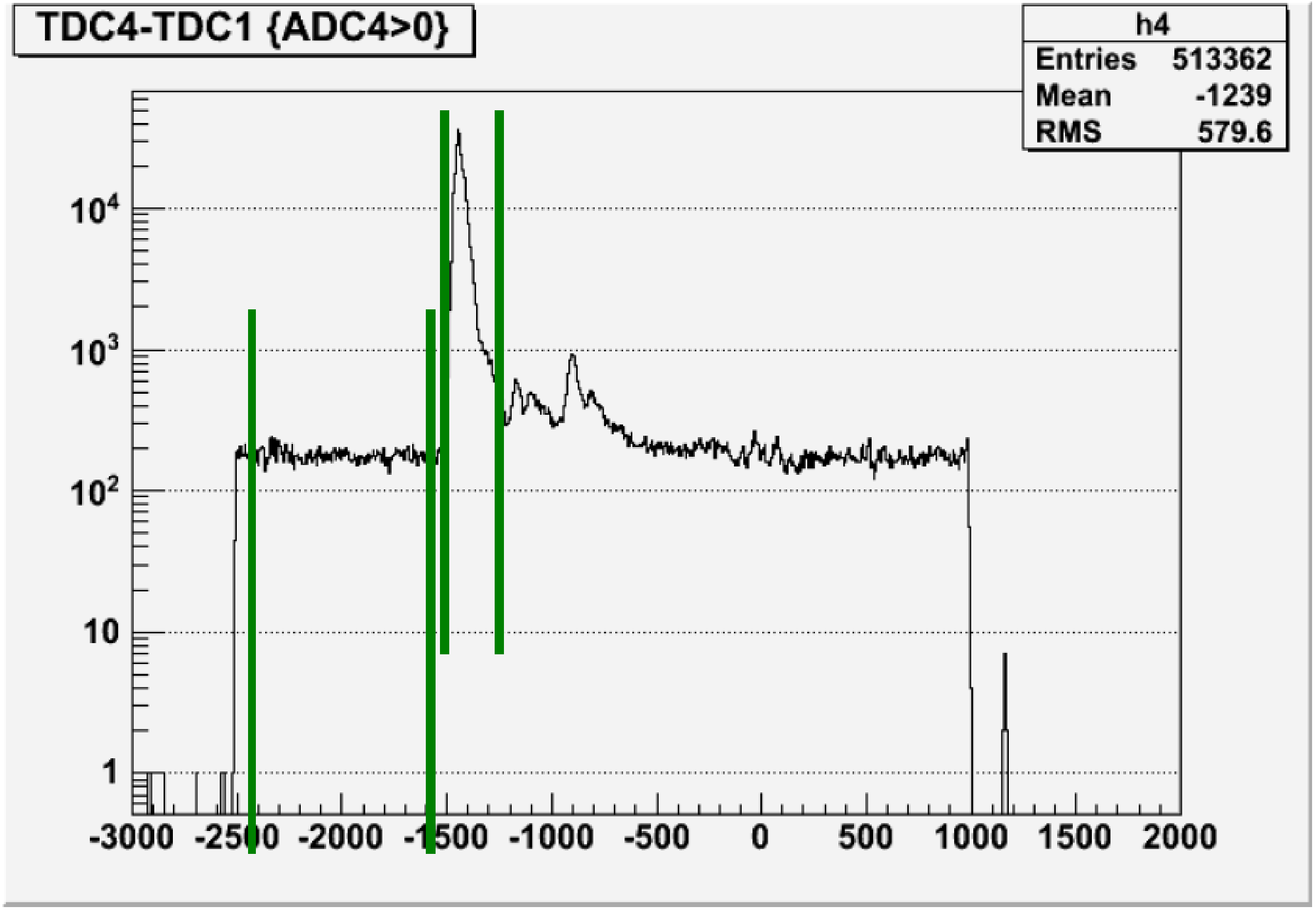




A quantitative PSD cut approach

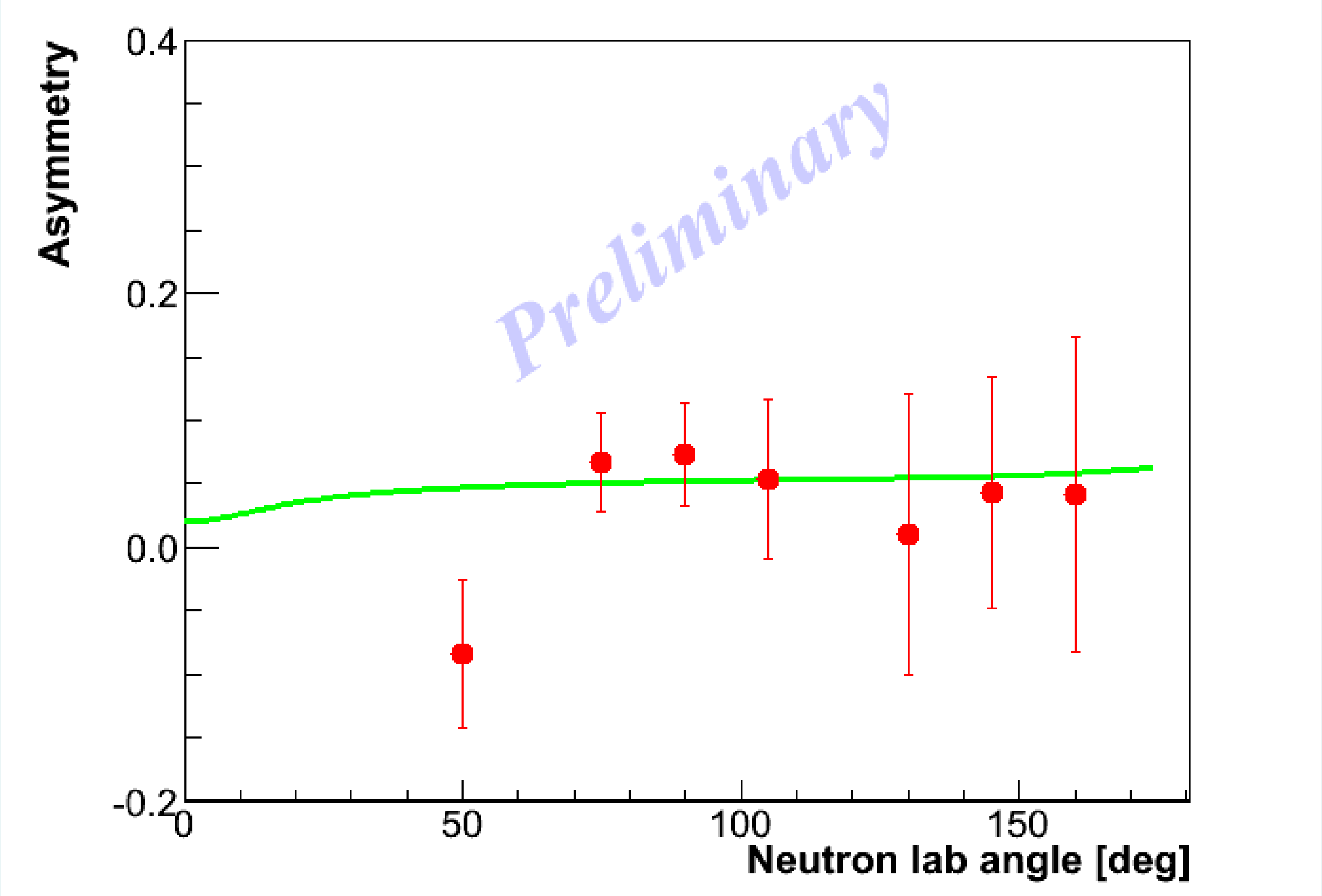


Event selection range



Method 1:
Integrate all the gammas before the gamma flash of all detectors, and use this as flux normalization
Method 2:
Integrate the gamma flash.

Asymmetry Preliminary Result



Calculation: Deltuva et al. (see previous slide)

Findings from Last May's HIGS run and new developments

- We successfully conducted a first asymmetry measurement, results are consistently with Deltuva's theoretical results (Golak et al's also).
- Large neutron background from GE180 glass material and air made data analysis difficult and reduced experimental statistics.
- A new Sol-Gel coated pyrex ^{3}He target was

  Constructed and tested since, achieved 64% polarization

  using an additional narrowed line-width laser
- Automated target motion system designed, is being built and tested

Beam Test of sol-gel coated pyrex target, May 2009

Six layers (from top to bottom): Al, D_2O, empty, N_2, D_2, ^{3}He.

Automated motor control made target switch faster and easier, reduce overhead time.

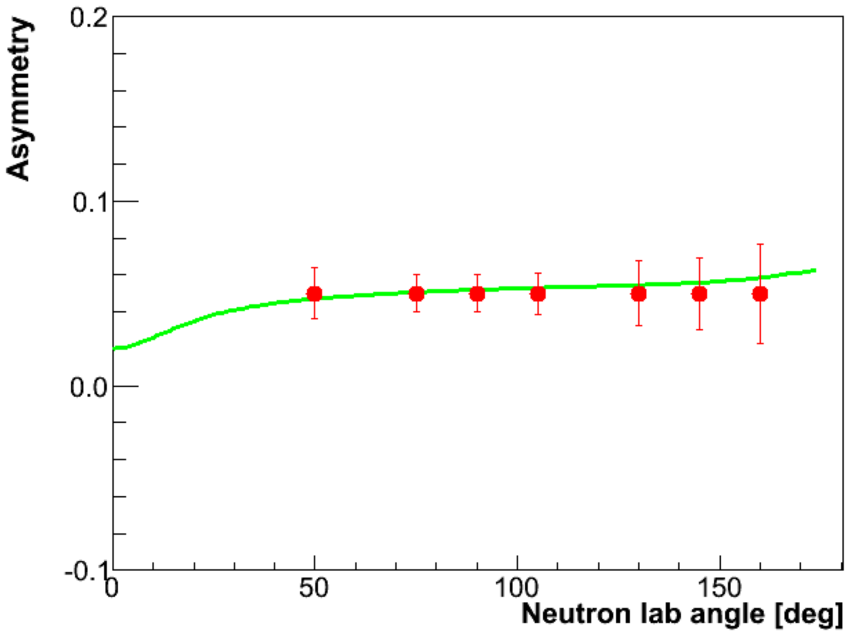
Findings from May Test Run

- Sol-Gel coated pyrex glass has fewer background events, 40% less yield compared with GE180.

Experimental challenges

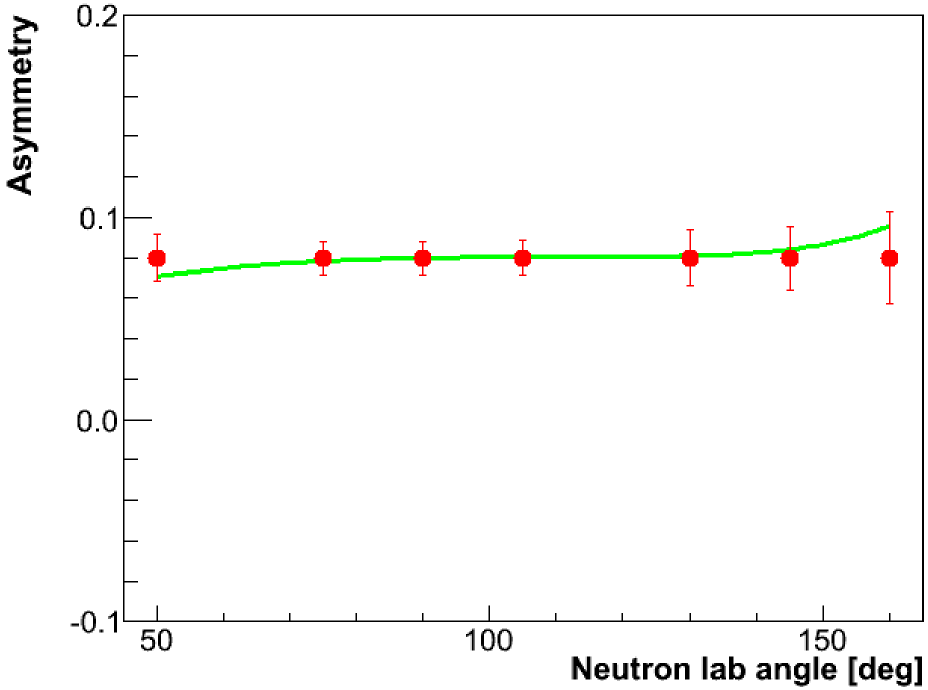
- Flux: we request stable and high flux, at least $5*10^7$/s
- Flux measurement: it is crucial for helicity-dependent cross section difference measurement, we need to know relative flux measurement to better than 1%.
- Photon flux monitor using downstream D_2O target, needs better shielding of neutrons.
- Need to make a vacuum pipe between the beam source and target. Reduce scatterings from the air.
- GEANT4 simulation will help to optimize the experimental configuration

Projections @10,20 MeV



11.4 MeV

20 MeV



11.4 MeV Projection:

Flux info from Ying Wu(8*10^7/s)

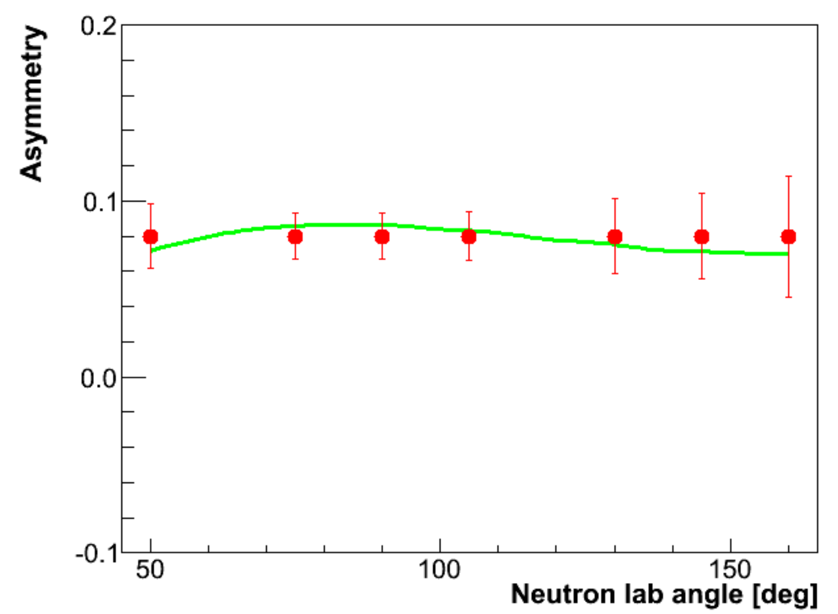
Time: 25 hrs each spin direction

Target thickness: 6*10^{21}/cm^2

Neutron detector eff from G4 simulation (~ 0.2)

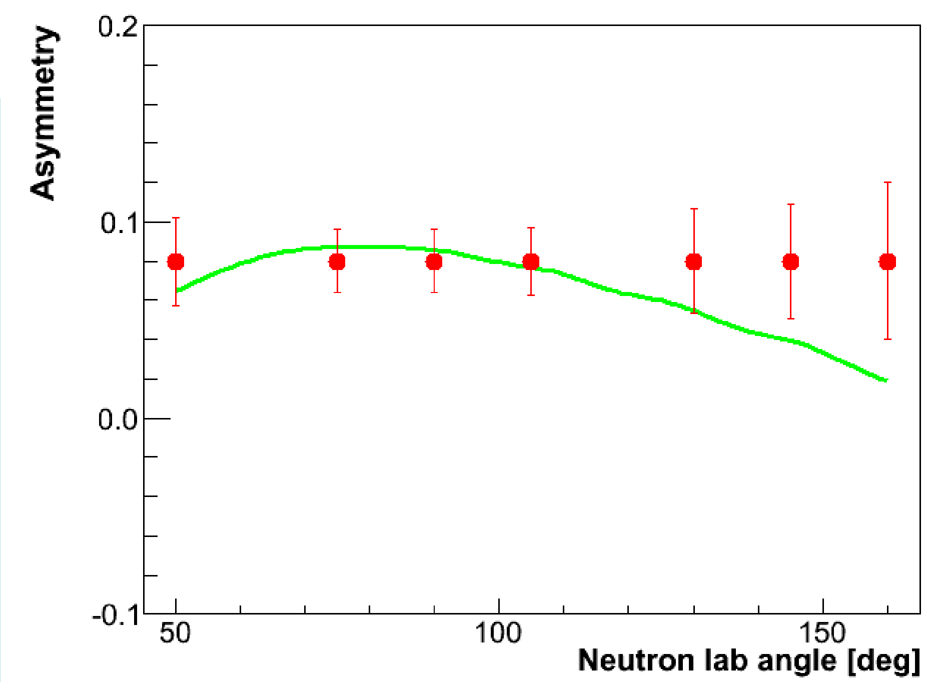
Target pol: 60%

Projection@ 30, 40 MeV



30 MeV

40 MeV



Flux: 5*10^7/s

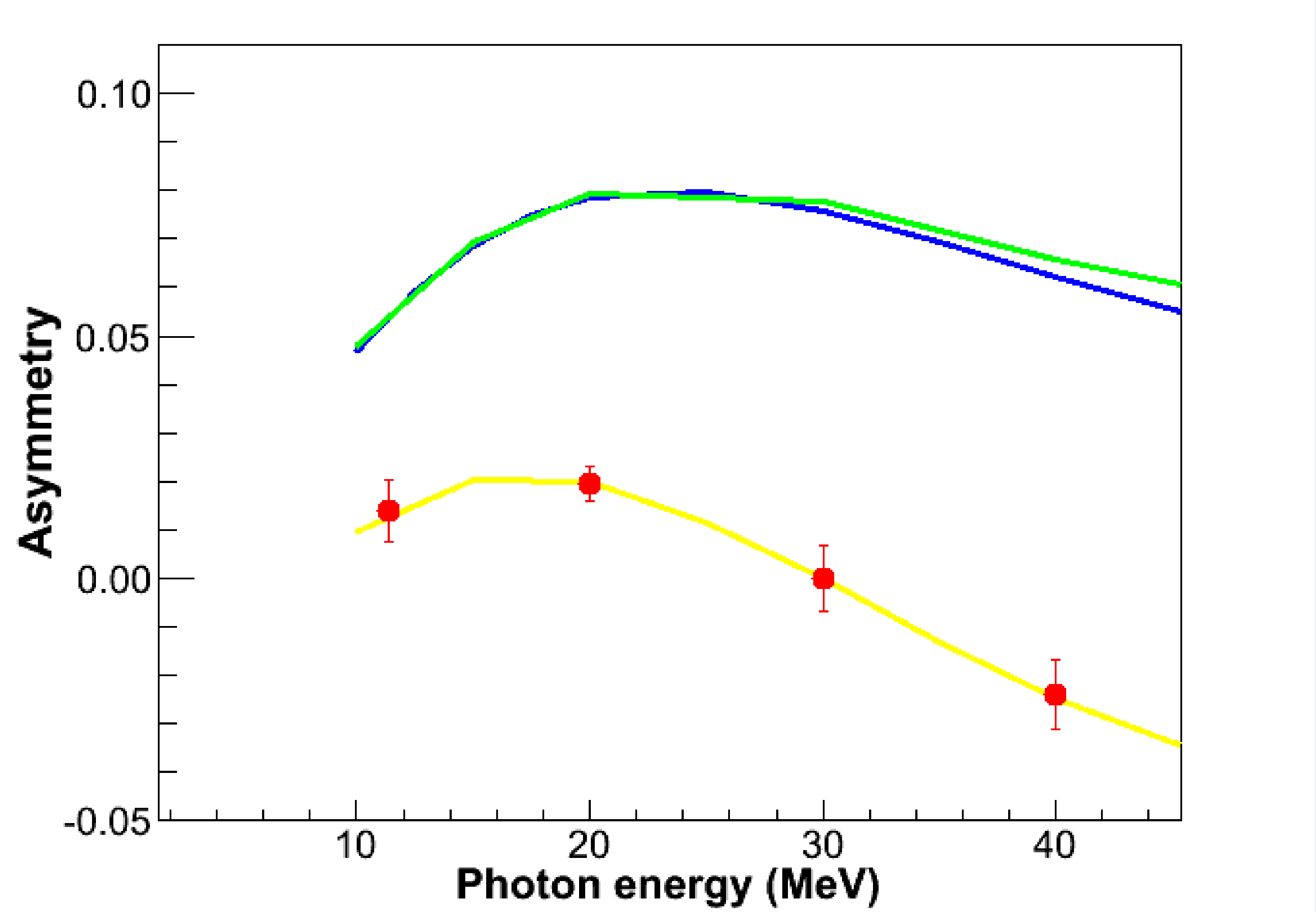
Other parameters are the same

Summary

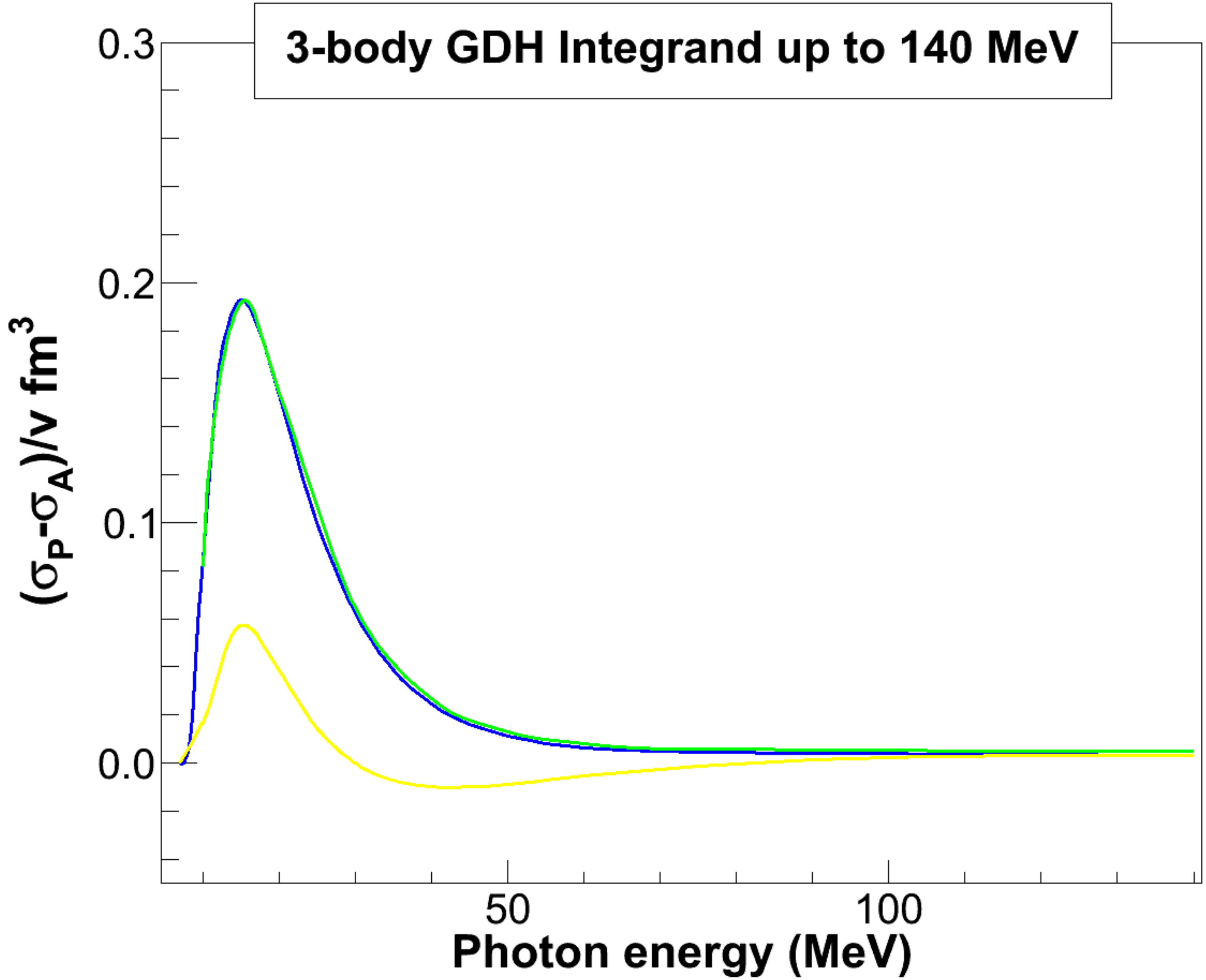
- We have performed a first asymmetry measurement from three-body photodisintegration of ^{3}He
- We requested 240 hrs HIγS beam time with a minimum photon flux of $5*10^7$/s for a photon energy spread of 3% to the PAC recently.
  - Measurement will test state-of-the-art 3body calculations, investigate three-body force effect,…
- Ultimate goal is to determine GDH integral on ^{3}He from 2body breakup threshold to pion production threshold.

Supported by U.S. Department of Energy under contract number DE-FG02-03ER41231

Projection: Asy VS. Eγ

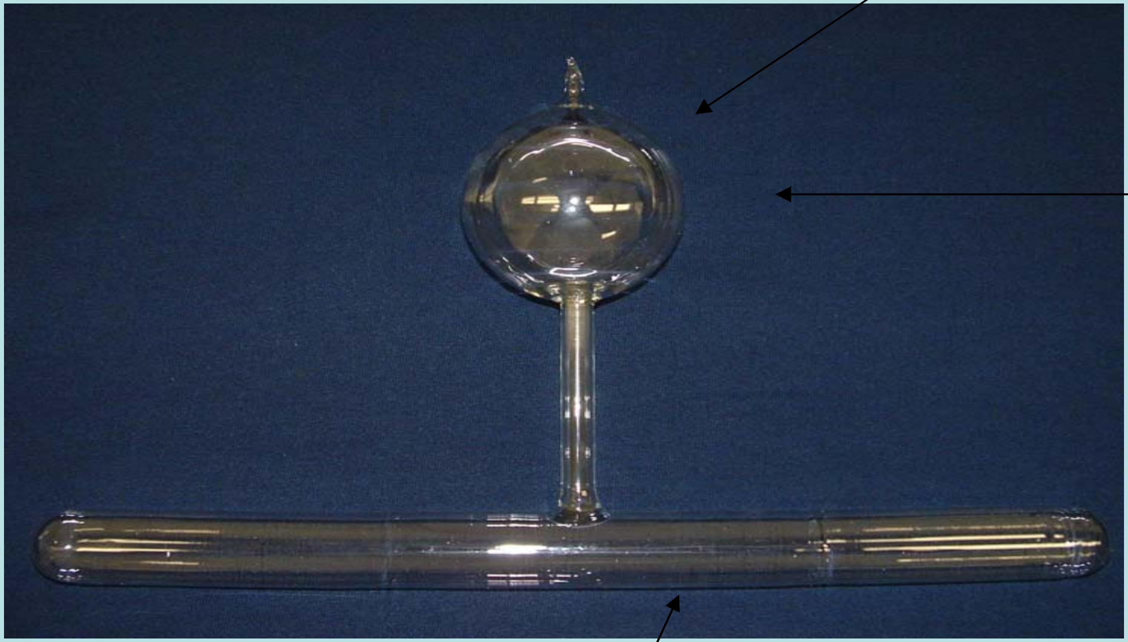


Theoretical calculations all from Deltuva, same notations in GDH plot



Calculations: Deltuva et al. And Golak et al. (see previous slide)

HIγS ^{3}He Target Cell



Pumping Chamber

7 amagats ^{3}He

We have Rb (Rb-K) and N_2 in the cell

Target chamber Length: 40cm

Diameter: 3cm