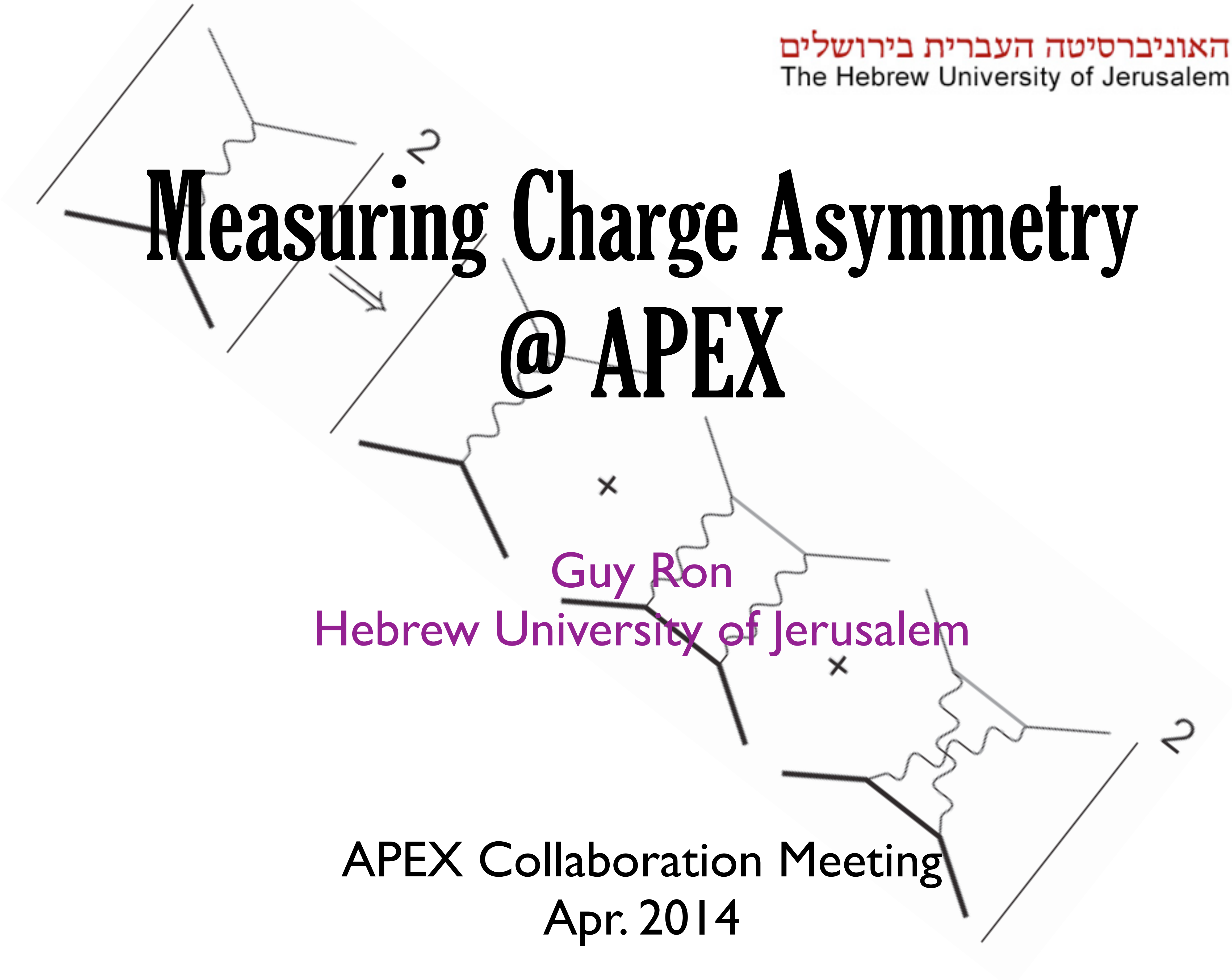
האוניברסיטה העברית בירושלים
The Hebrew University of Jerusalem

Measuring Charge Asymmetry @ APEX

Guy Ron
Hebrew University of Jerusalem

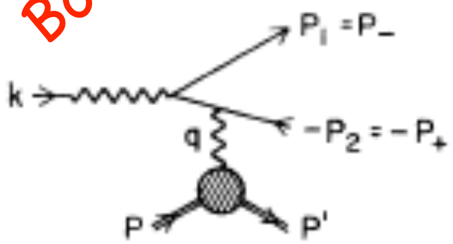
APEX Collaboration Meeting
Apr. 2014



Higher Order Bethe-Heitler

BH-LIKE PROCESSES

1st order Born



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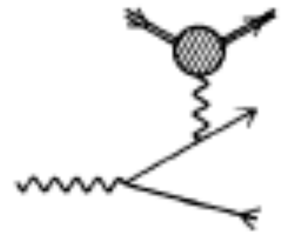

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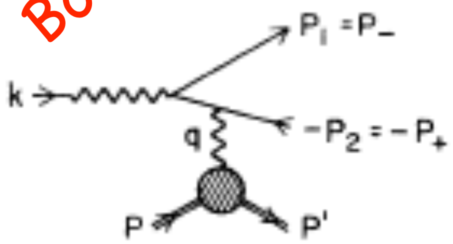

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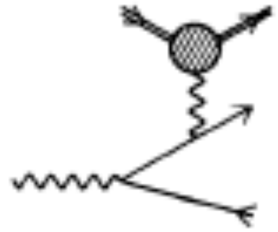
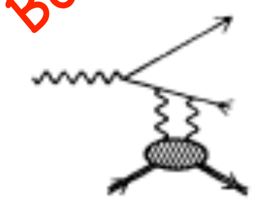
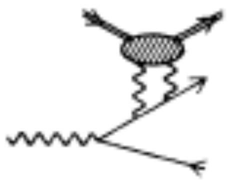
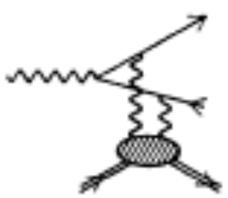


Interfere with

2nd order Born







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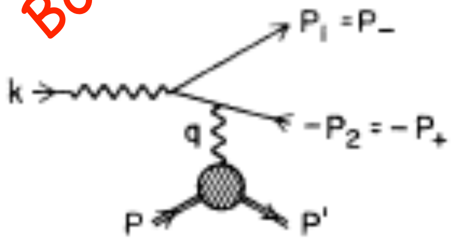

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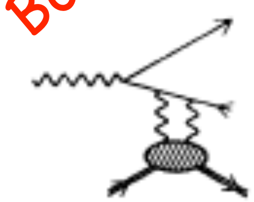
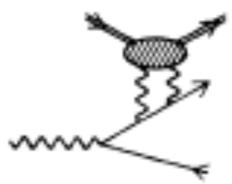
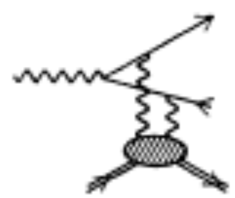
Interfere with

2nd order Born





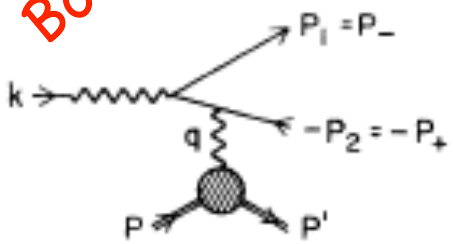


And with

Time Like Compton

BH-LIKE PROCESSES

1st order Born



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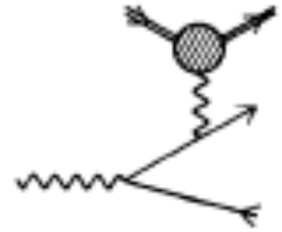

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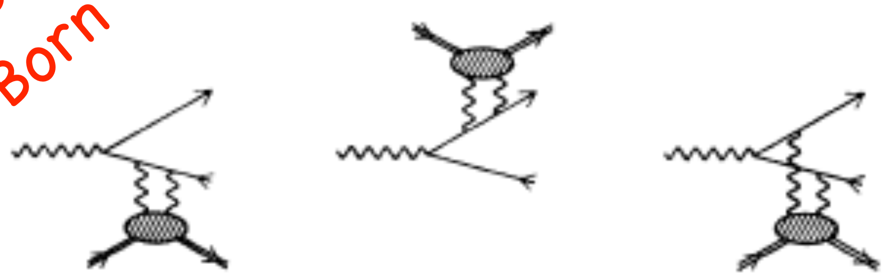
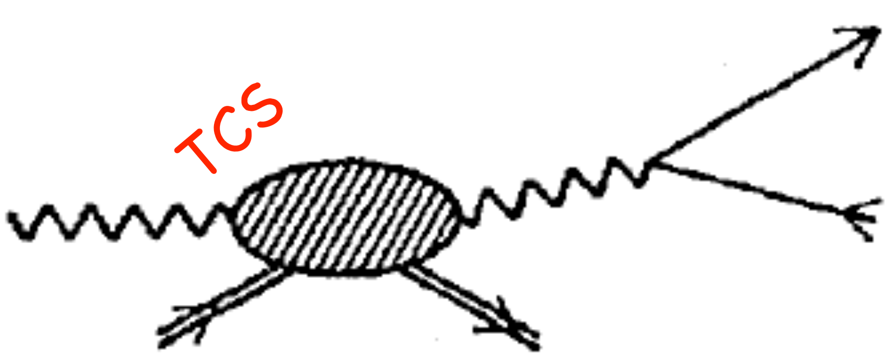
2nd order Born



And with

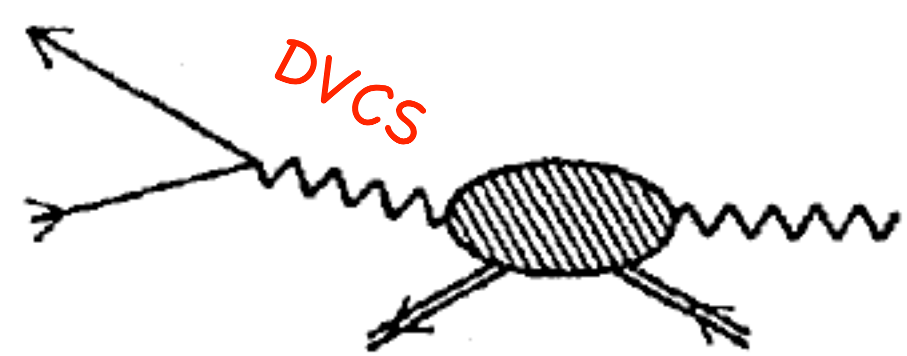
Time Like Compton

TCS



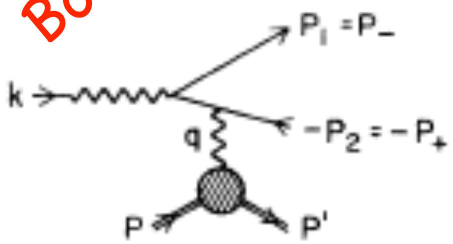
Time Reversal

DVCS



BH-LIKE PROCESSES

1^{st} order Born



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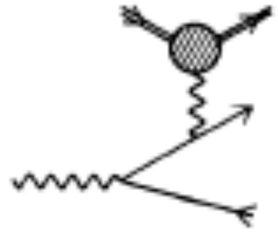
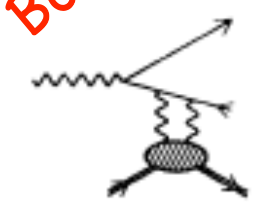
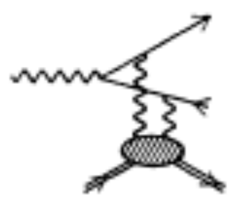


Interfere with

2^{nd} order Born





And with

Time Like Compton

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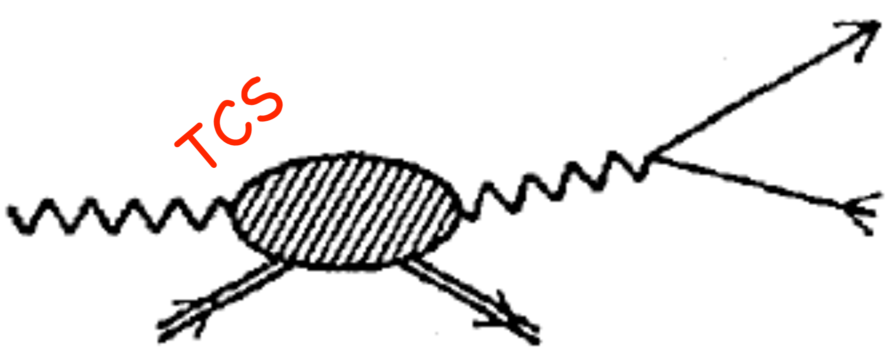

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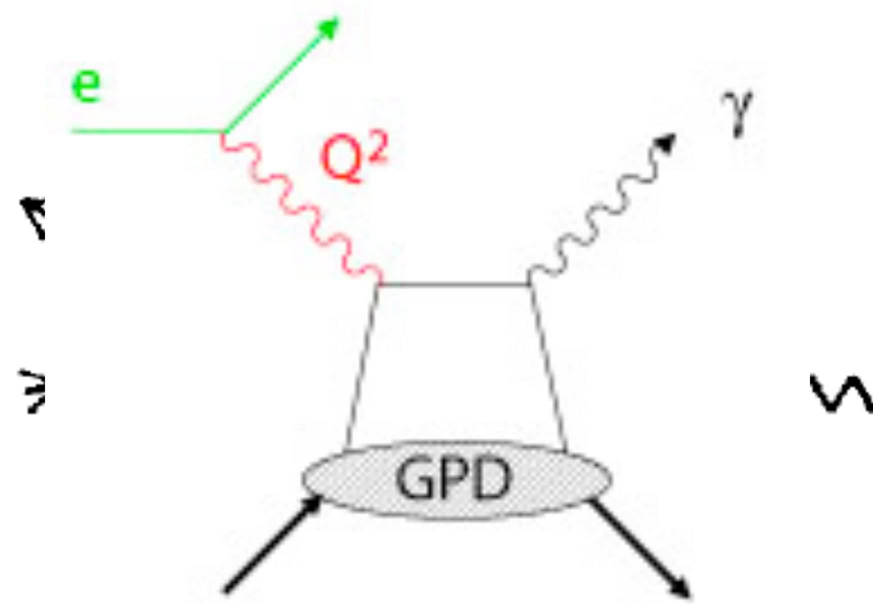


So what can we do with this?

The interference manifests itself as an asymmetry in the e^+/e^- pair. Either energy (equal angle) or angle (equal energy) should work.

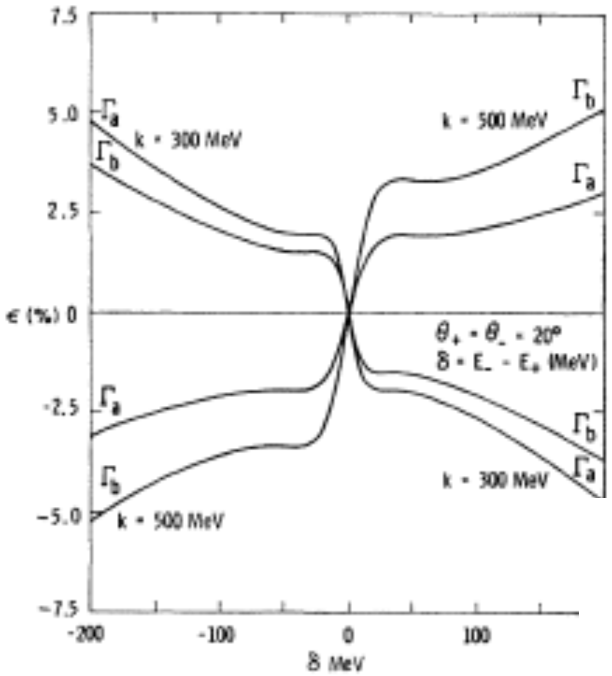
For example, to 1st order, the asymmetry in energy is:

$$\epsilon(\delta) = \frac{N_{e^+}(\delta) - N_{e^-}(\delta)}{N_{e^+}(\delta) + N_{e^-}(\delta)} = \frac{d\sigma_{int}}{d\sigma_{BH} + d\sigma_{Compton}}$$

Also measures real part of forward Compton Amplitude:

$$\varepsilon \simeq (\delta/M)\theta^2 \left[-(M_p/\alpha)\mathrm{Re}A(\omega, 0^\circ)\right]$$

THESE ASYMMETRIES ARE NOT SMALL



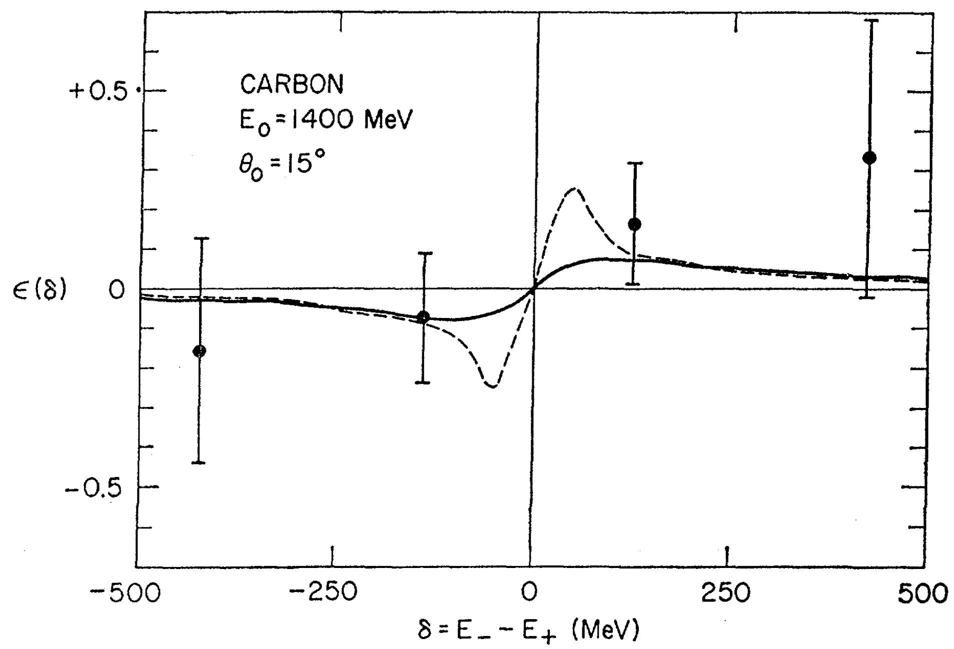


FIG. 4. Electron-positron asymmetry in pair production on carbon for invariant pair mass $m(e^+e^-)=770\pm50$ MeV (the ρ^0-dominated region). The definition of $\epsilon(\delta)$ is given in Sec. I. The experimental points are the binned results of Ref. 7. The dashed curve is the second Born spin-zero result given in Sec. IV for mirror-symmetric (except for energy, $\delta=E_1-E_2$) pairs produced in a Yukawa charge distribution, with $\mu=204$ MeV chosen to fit the carbon rms radius. The solid curve is obtained by averaging the cross sections over lepton angles in order to approximate the experimental acceptance, as discussed in the text.

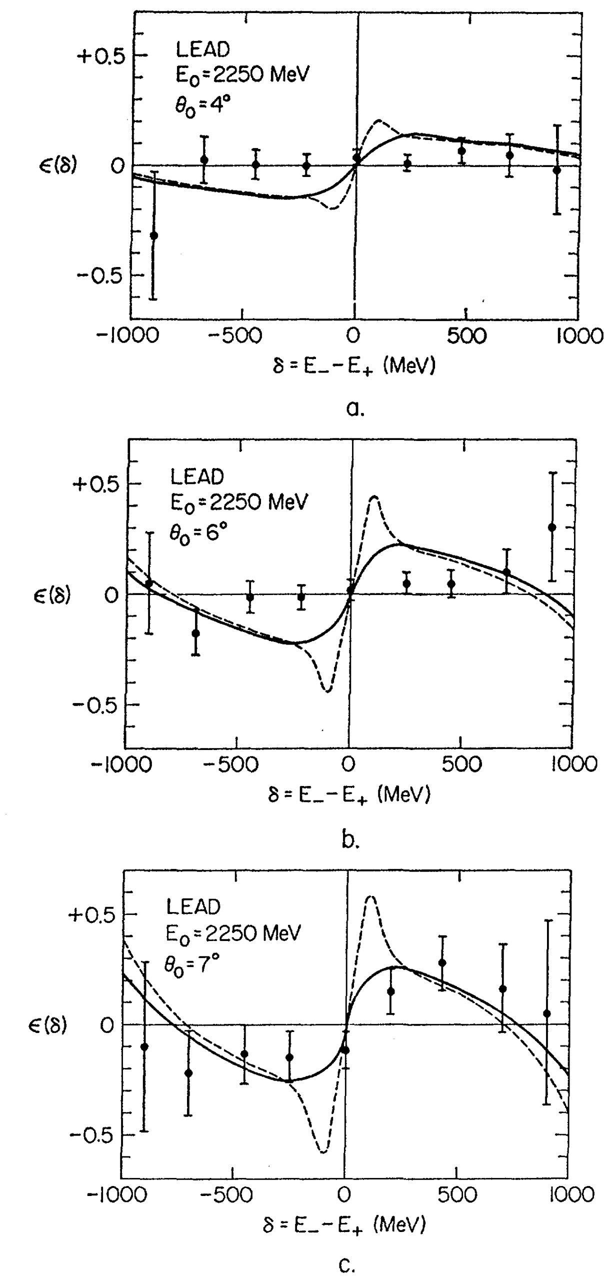


FIG. 5. Electron-positron asymmetry in pair production on lead for invariant pair mass in the interval $300\leq m(e^+e^-)\leq550$ MeV. The experimental points are from Ref. 7. The dotted curve is the predicted differential cross section for mirror-symmetric (except for $E_- - E_+ = \delta$) pairs produced in a Yukawa charge distribution, with $\mu=89.5$ MeV chosen to fit the electromagnetic rms radius of lead. The solid curve is obtained from an average over lepton angles to provide a first approximation to the experimental acceptance (see text). The asymmetry for $|\delta|\leq300$ MeV will be reduced when the theoretical prediction is averaged over the finite binning size and the actual experimental acceptance.

Brodsky and Gillespie.
Asbury.

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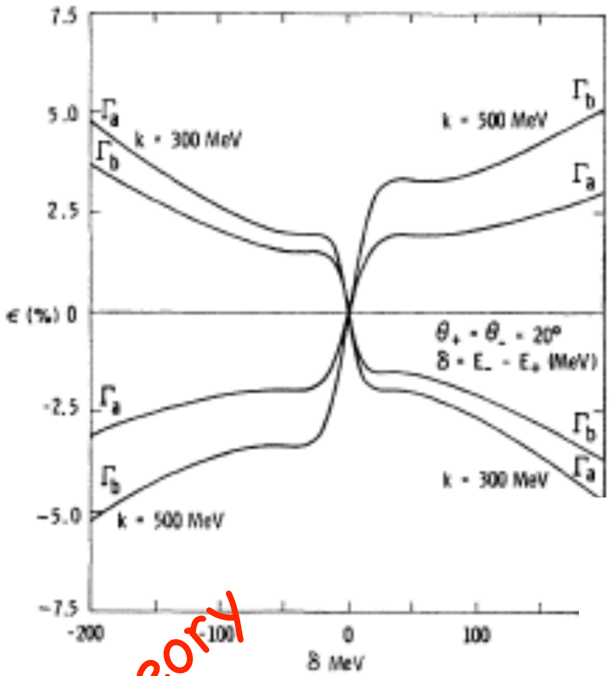

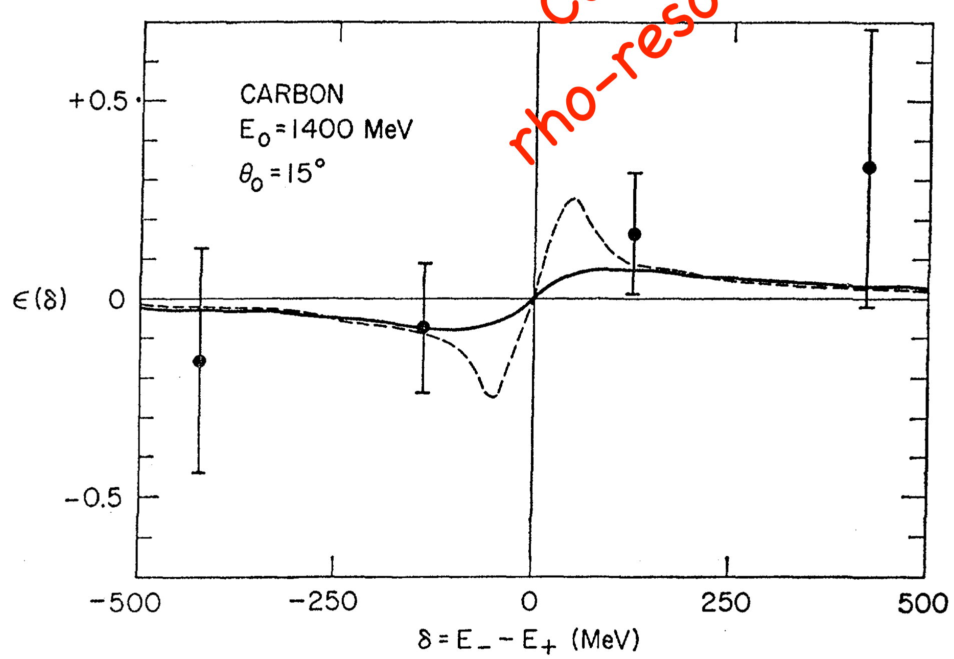

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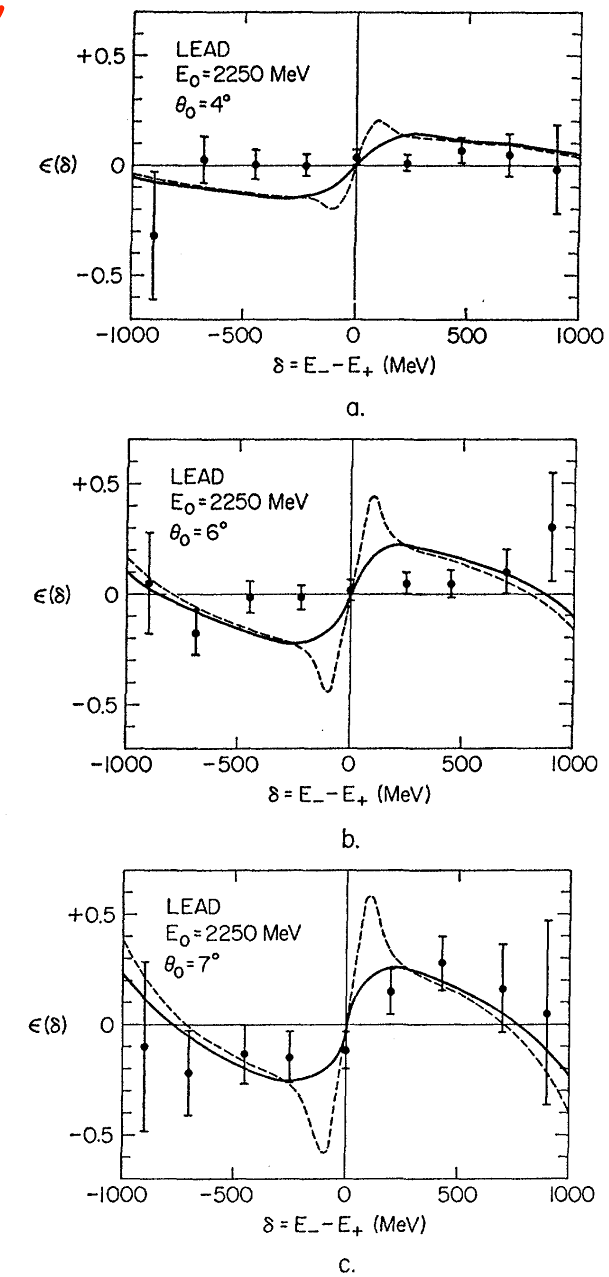

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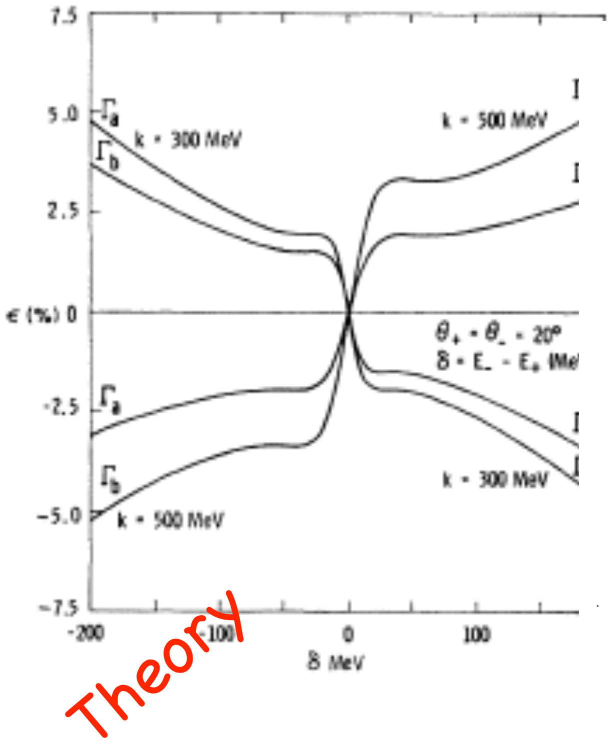
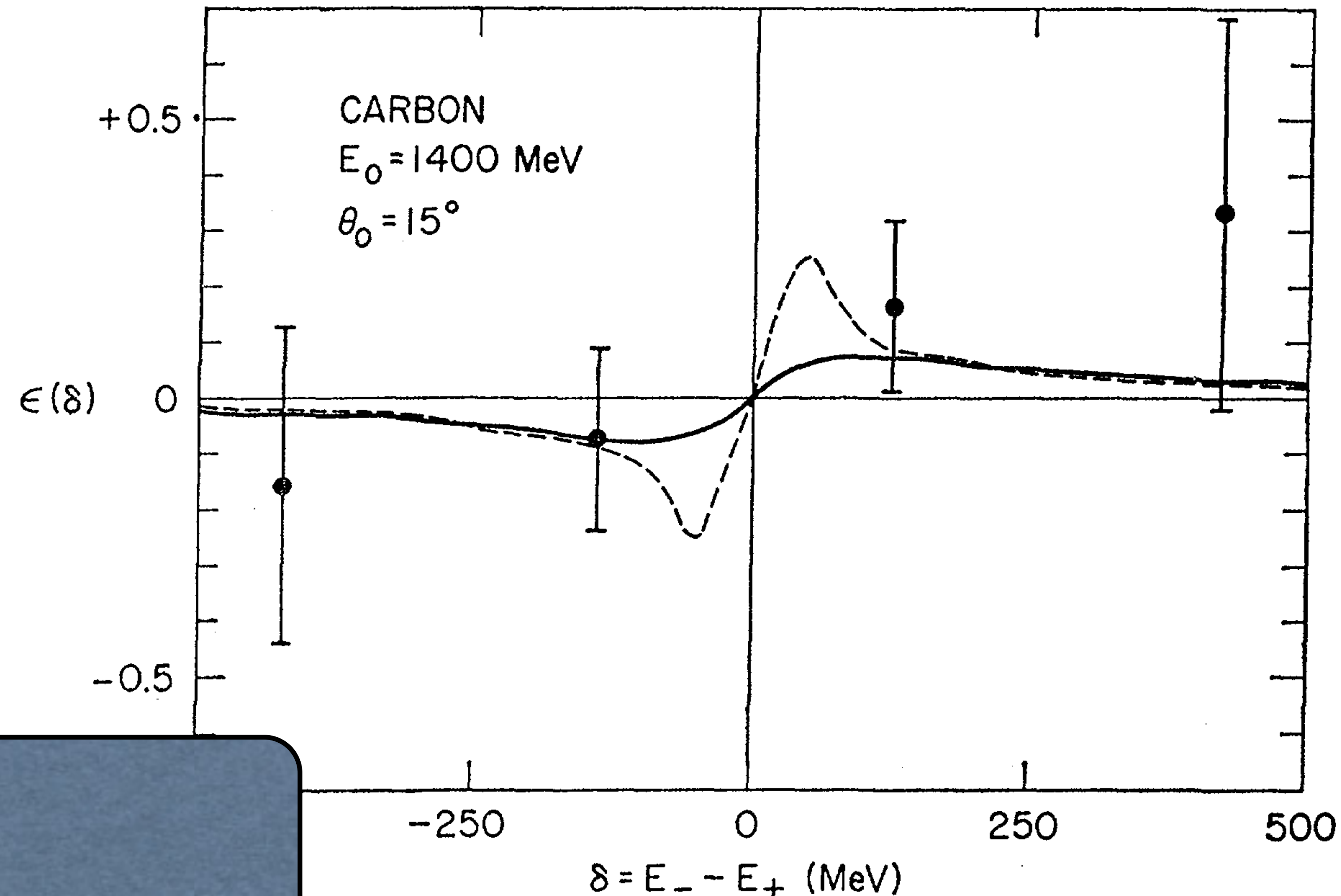
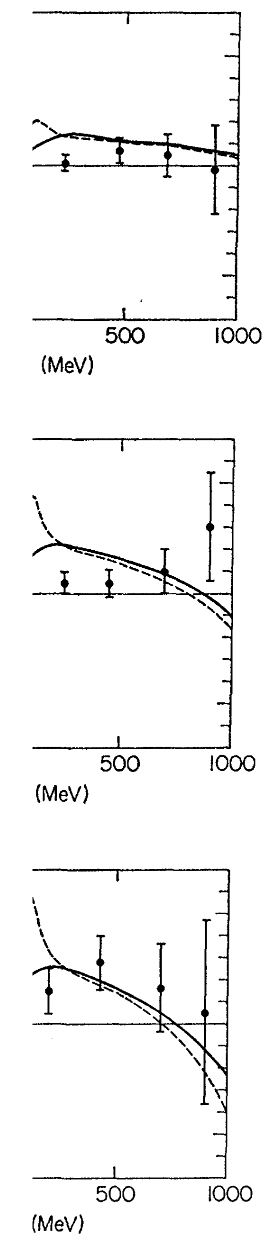
Brodsky and Gillespie.
Asbury.

BUT THEY ARE ALSO NOT WELL MEASURED







And calculated using scalar QED

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Brodsky and Gillespie.
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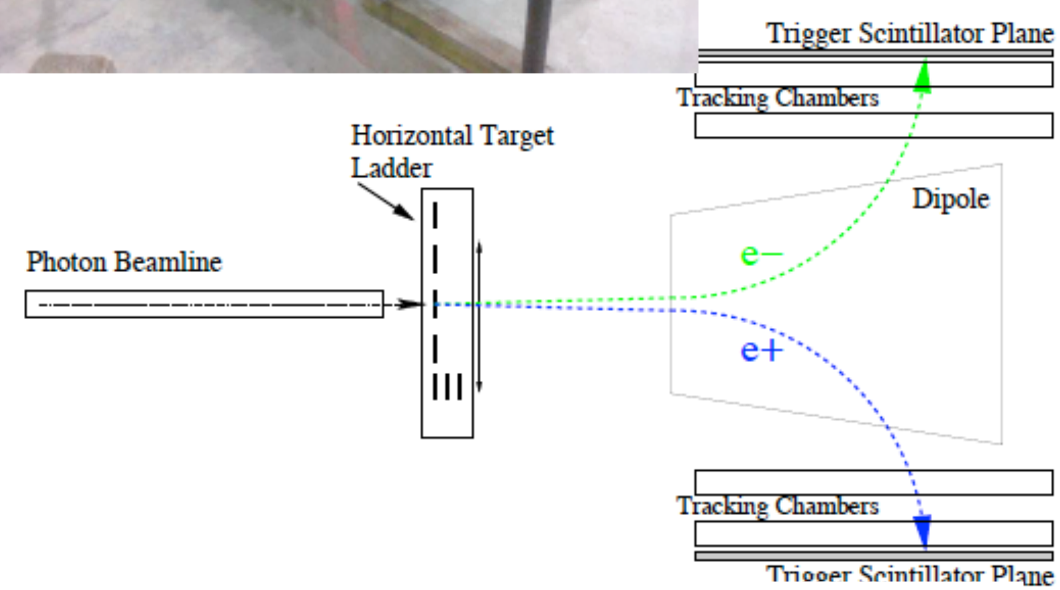
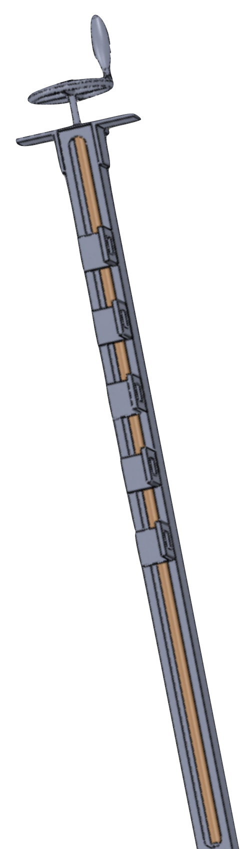
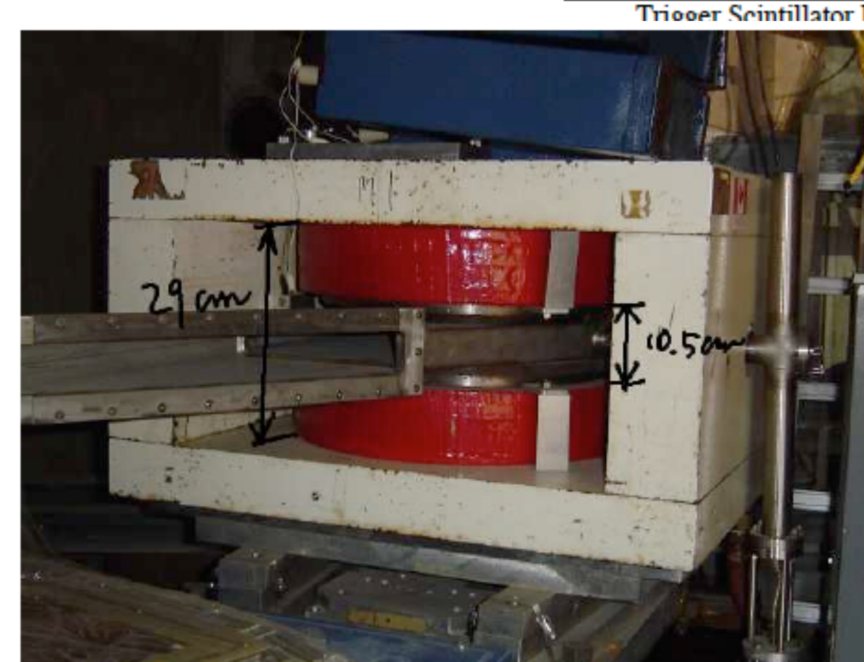
New Experimental Effort

- 60 MeV Photon beam at HIgS.
- Reusing Magnets/Wire Chambers/Spectrometers.
- Approved for 150h on ^{12}C/ ^{238}U, to be followed by proton target (CH_2).
- New theory calculations by S. Milshtein (JINR) - real QED, all orders in αZ (non perturbative QED).
- Will run 2015(?).







New Experimental Effort

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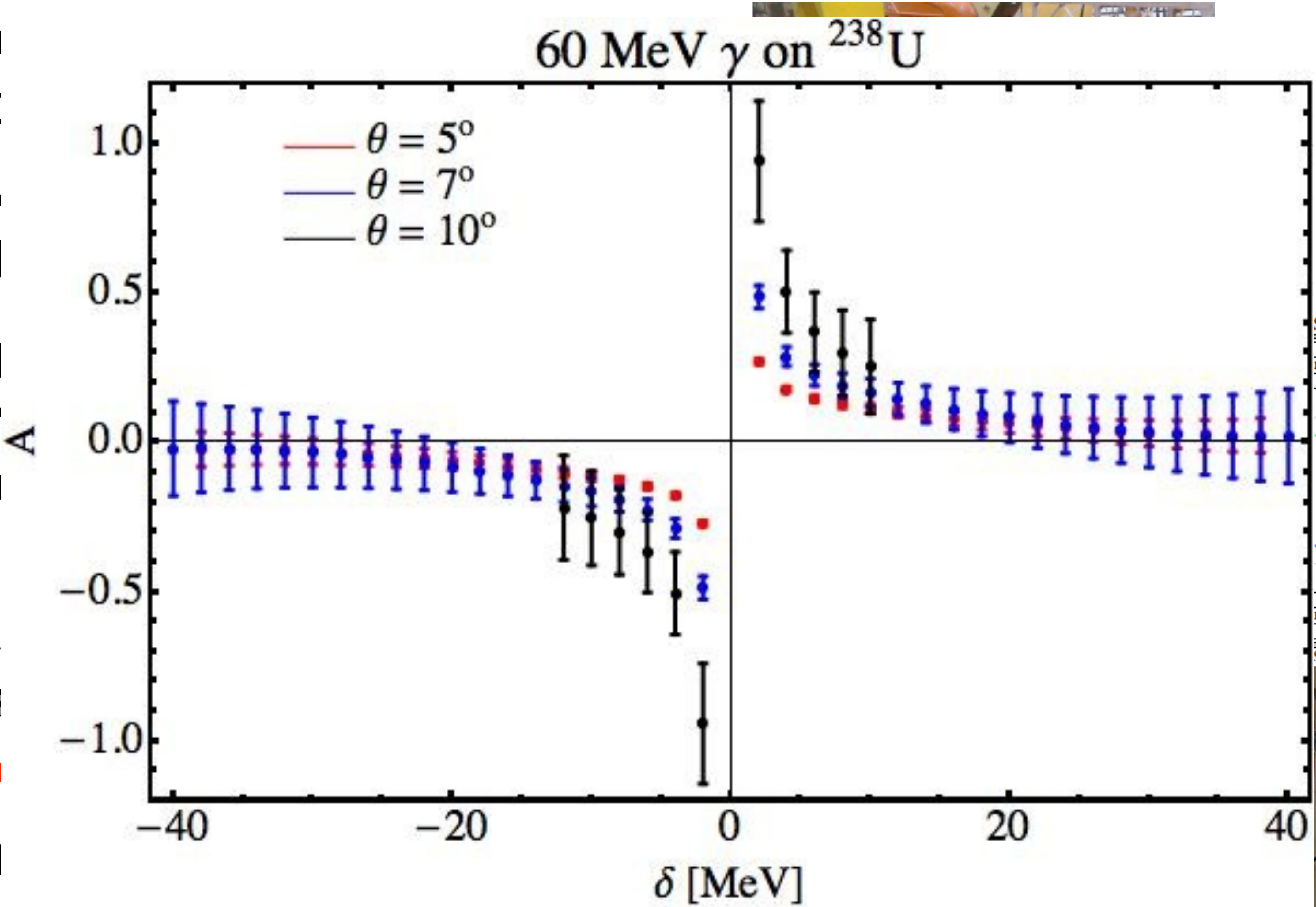

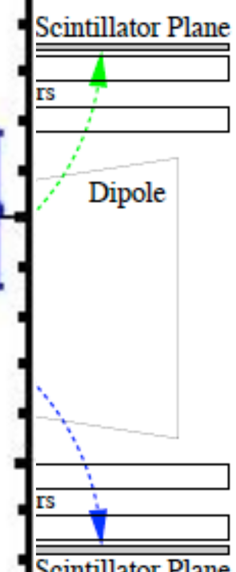

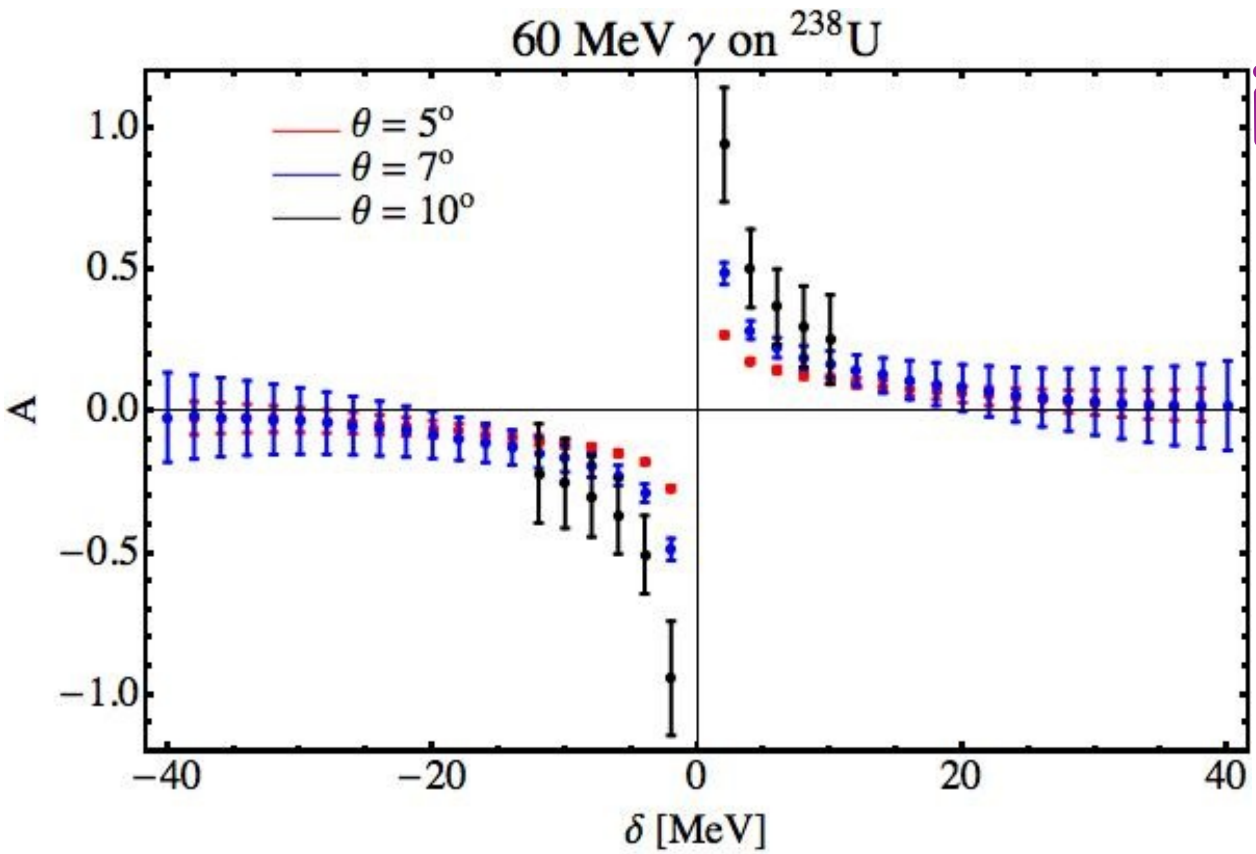

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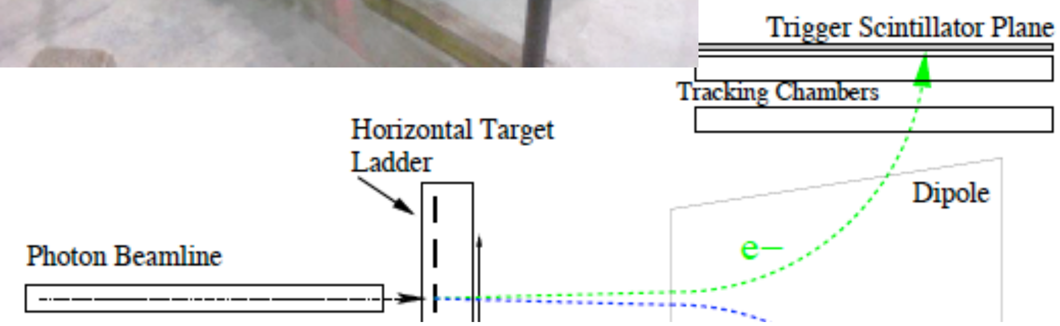

^{238}U, to be followed by proton target (CH_2).

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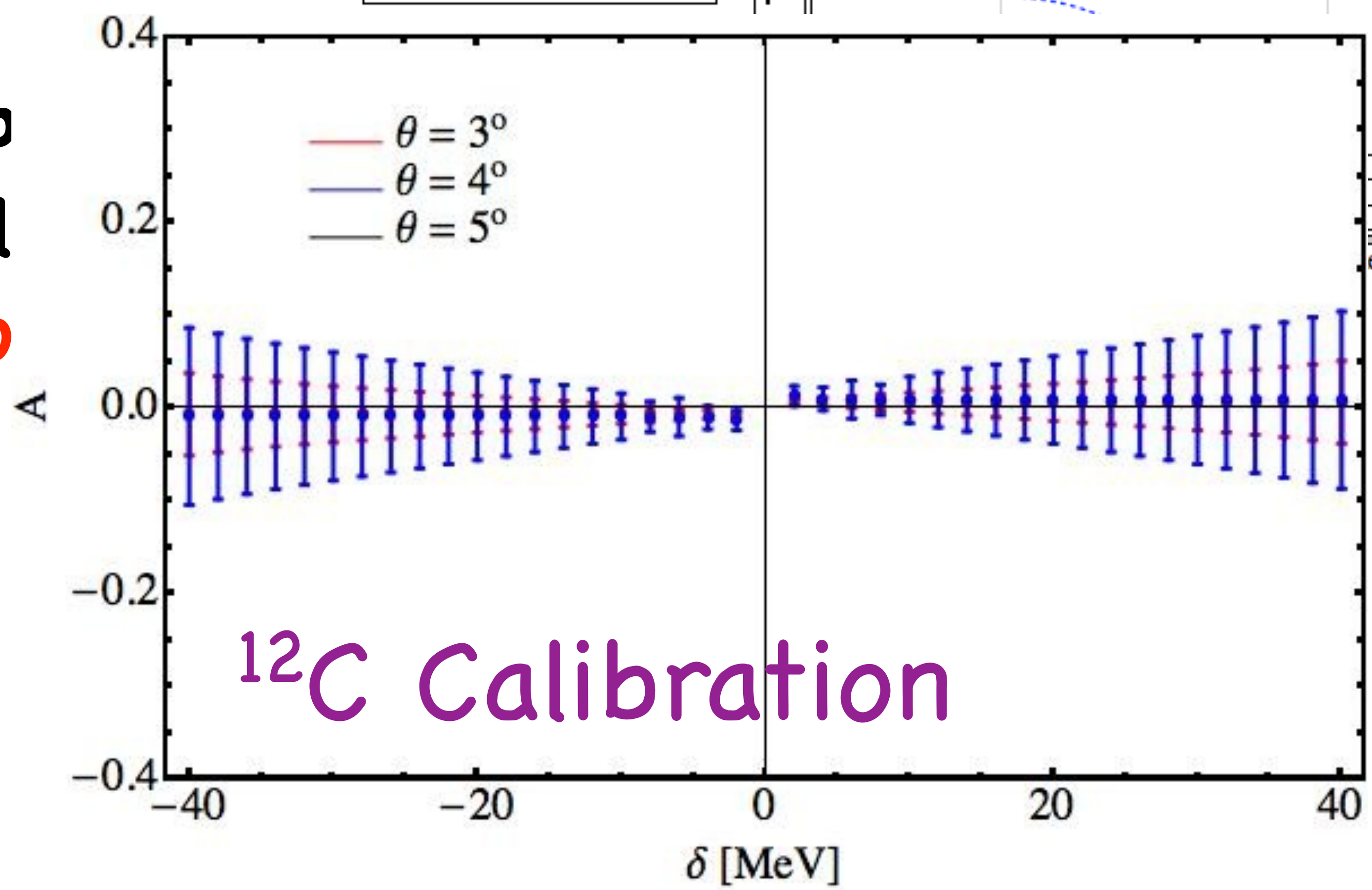
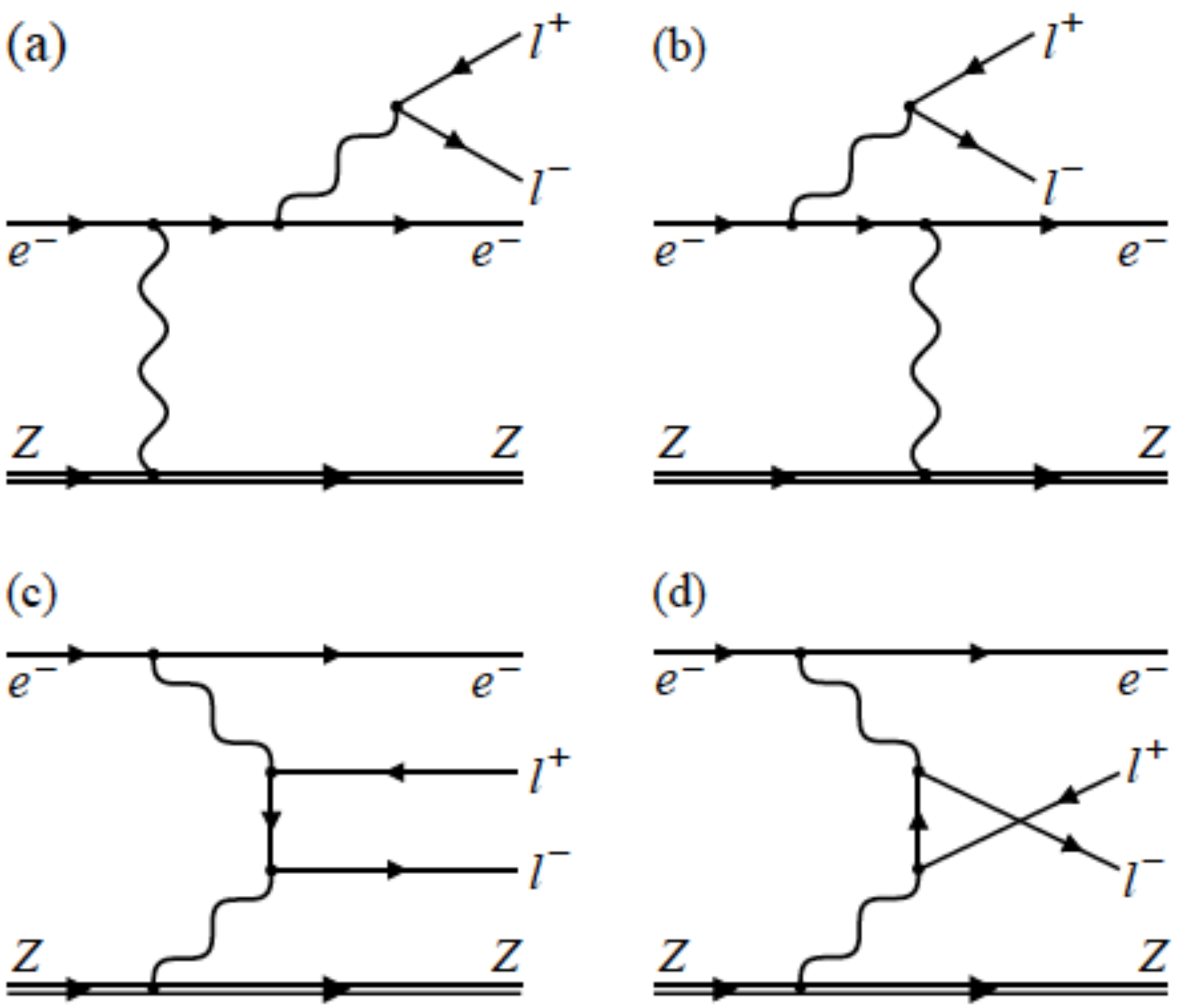


^{12}C Calibration

Wouldn't it be nice to go to higher energy?

- Photon beam fluxes are low... Almost impossible to do well (Hall D?)
- What about virtual photons?
- Much higher flux.
- Well controlled e beam.
- Interference from "initial state" diagrams makes calculation very hard - do not currently have good calculation (maybe need to think some more about it...).



Will Allow us to:

- Scan across vector meson resonances - probe hadronic component of photon?
- Extract forward Compton amplitude of resonance - also will give nuclear matter modification.

But maybe....

- μ pair production asymmetry recently calculated (E. J. Downie, R. N. Lee, A. I. Milstein, GR, PLB 728, 645 (2014)).
- Calculation somewhat easier than for electrons (Coulomb corrections suppressed due to higher muon mass).
- Asymmetry essentially independent of nuclear form factor.
- Direct test of Lepton universality in QED.
- Very much suited to APEX kinematics.

	JLab	Mainz
Beam Energy	2.2 GeV	1.5 GeV
Current	50 μA	50 μA
Detector Package	HRS + Septa magnets (see text)	Dedicated (see text)
Detector Angle	5°	5°
Target	^{238}U (25 μm)	^{238}U (25 μm)

But maybe....

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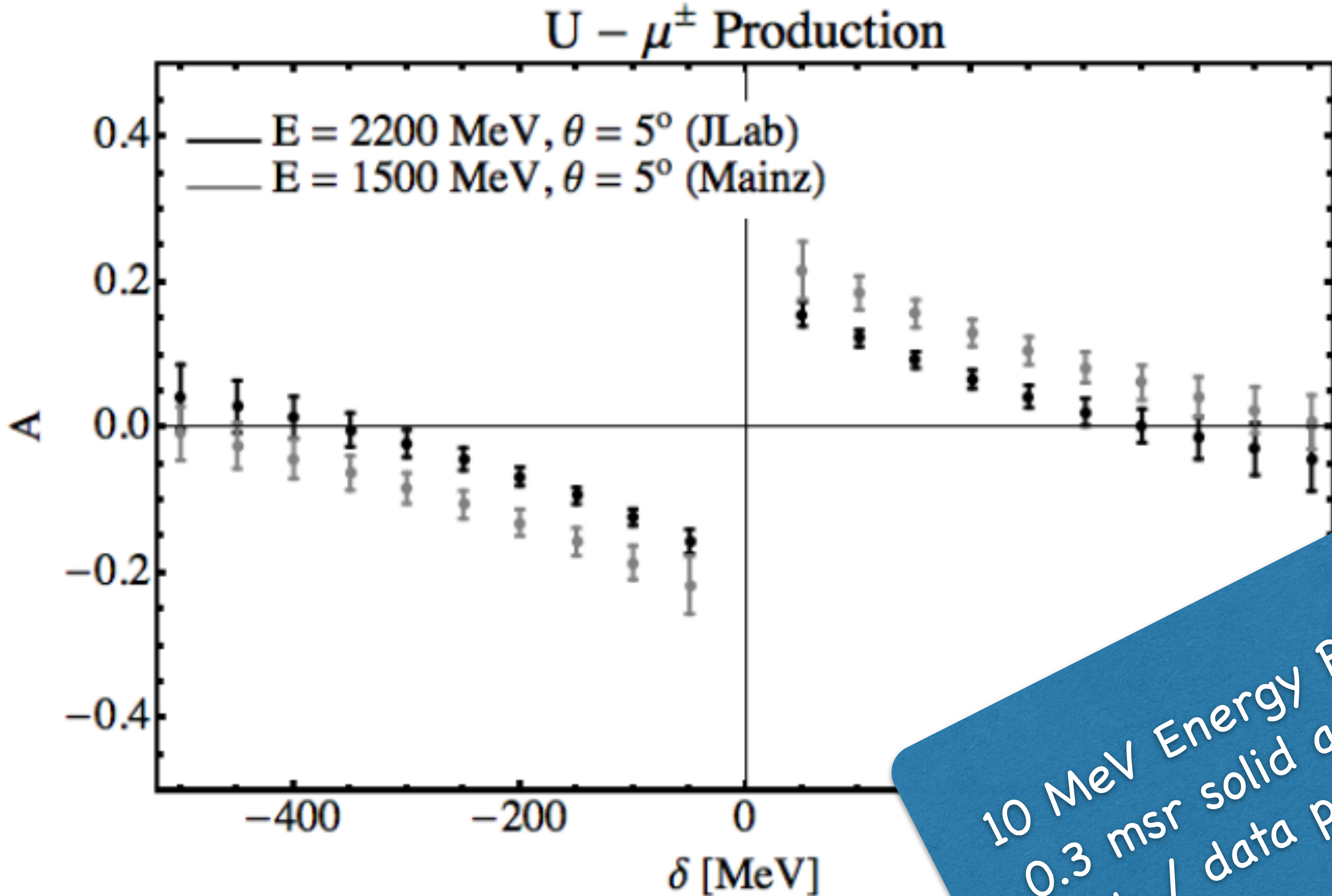

Target	^{238}U (25 μm)

10 MeV Energy Bins
0.3 msr solid angle
3h / data point

What's needed?

- Better look at backgrounds - requirement for 2 muons gives strong background suppression, but need to do well on mu/pi separation.
- Recalculate expected asymmetry for APEX target/settings - will lose a bit on W vs. U, but on the other hand the solid angle is actually much bigger.
- Get support from APEX.....
- Write/submit proposal.
- Run with APEX (can very probably run even before APEX as part of commissioning).

What we get

- Test of non-perturbative QED.
- First ever measured asymmetry in mu pair-production.
- Lepton universality test (not v. high accuracy - limited by knowledge of FF, but purely QED).
- Extend use of APEX setup.
- Springboard for new class of experiments @ JLAB?
- Question I do not have an answer for:
  - What if one of the two photons is an A'???
  - Can we think of this as another A' search idea?

The BH Collaboration

- GWU: Evangeline Downie
- HUJI: Guy Ron
- JLab: Brad Sawatzky, Doug Higinbotham
- UVa: Blaine Norum, Richard Lindgren
- U. Saskatchewan: Rob Pywell

More collaborators more than welcome....

Summary

- Over the past 40 odd years we've encountered 2-photon effects time and time again.
- They've helped us learn about QED, QCD.
- A new generation of experiments can be performed where these effects are used.
- APEX eminently suited for this.

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Higher order effects are a problem

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- A new generation of experiments can be performed where these effects are used.
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Higher order effects are a probe