# DVCS Collaboration Meeting

February 1, 2020

## DVCS Cross Section Analysis Update
## Kin 48

Alexa Stefanko

# General expression of the cross section:

$$\frac{d^4\sigma}{dQ^2 dx_B dt d\phi} = \sum_{n=0}^{N} F_n(E, Q^2, x_B, t, \phi) X^n$$

Kinematic factors - found from MC data

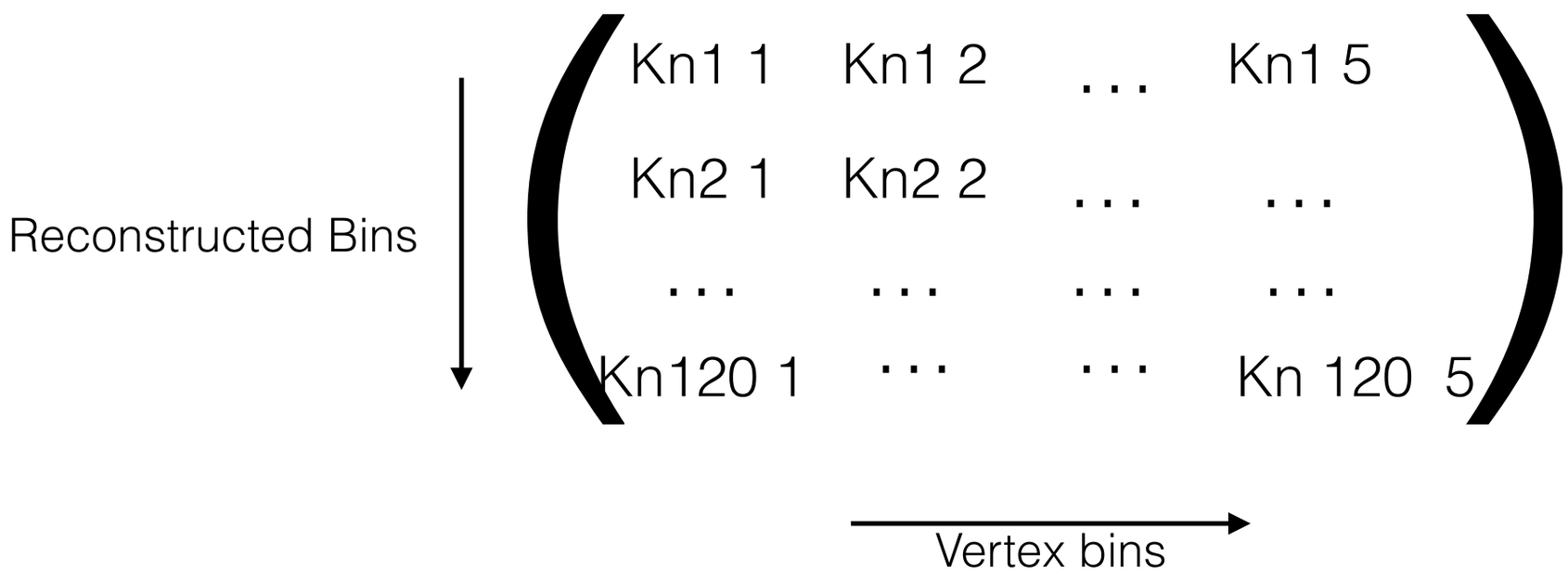
"n" combinations CFFs we want to extract by fitting MC to experimental data

- Test different combinations of CFFs to find the best fit for polarized and unpolarized cross sections

# Create a V x R matrix for each “n” CFF combination

$$\mathcal{K}^n_{rv} = \int_{\Phi^r_v} \mathcal{F}_n(E, Q^2, x_B, t, \phi) d\Phi \ ,$$

$$= \sum_{i \in r \bigcap v} \mathcal{F}_n(E^i_v, (Q^2_v)^i, (x_B)^i_v, t^i_v, \phi^i_v) \frac{\Gamma^i_{MC}}{N_{gen}}$$



# To minimize Chi2… find A and B:

Square matrix

$$A_{nv,n'v'} = \sum_{r=1}^{\mathcal{R}} \mathcal{L}^2 \frac{K_{rvn} K_{rv'n'}}{\left[\sigma_r^{data}\right]^2}$$

Dimension: (N*V) x (N*V)

Column Vector

$$B_{nv} = \sum_{r=1}^{\mathcal{R}} \mathcal{L} \frac{K_{rvn} N_r^{data}}{\left[\sigma_r^{data}\right]^2}$$

Dimension: N*V

$$\langle X_n \rangle_v = \sum_{n'=1}^{\mathcal{N}} \sum_{v'=1}^{\mathcal{V}} \left[A^{-1}\right]_{nv,n'v'} B_{n'v'}$$

Use V x R matrices to find Nr (MC) for each vertex (t) bin

$$N_r = \sum_{v=0}^{\mathcal{V}} \sum_{n=0}^{N} \mathcal{K}_{rv}^{n} X_v^n$$

$$\begin{pmatrix} \text{Kn1 1} & \text{Kn1 2} & \cdots & \text{Kn1 5} \\ \text{Kn2 1} & \text{Kn2 2} & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots \\ \text{Kn120 1} & \cdots & \cdots & \text{Kn 120 5} \end{pmatrix} \begin{pmatrix} \text{Xn1} \\ \cdots \\ \text{Xn5} \end{pmatrix}$$

Fit Nr (MC) to Nr (exp) to extract the n combinations CFFs for each vertex bin

$$\chi^2 = \sum_{r=0}^{\mathcal{R}} \left( \frac{N_r^{exp} - N_r^{MC}}{\sigma_r^{exp}} \right)^2$$

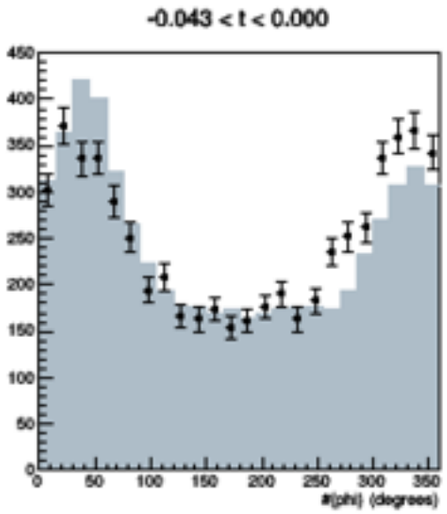
$$N_r = \sum_{v=0}^{\mathcal{V}} \sum_{n=0}^{N} \mathcal{K}_{rv}^{n} X_v^n$$

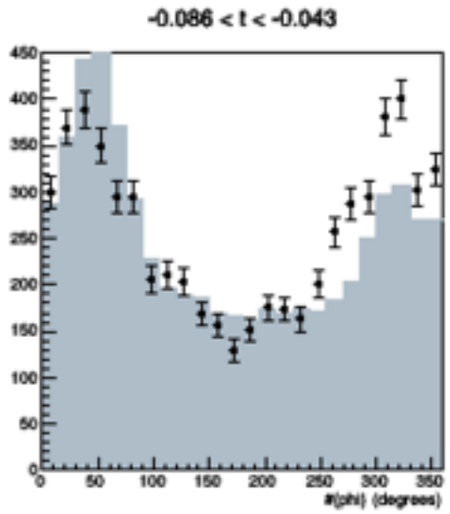
$$\frac{d^5\sigma_v^{fit}}{dQ^2 dx_{Bj} dt d\phi d\varphi} = \sum_{n=1}^{\mathcal{N}} F_n(E, \langle Q^2 \rangle, \langle x_{Bj} \rangle, \langle t \rangle, \phi, \lambda) \langle X_n \rangle_v$$

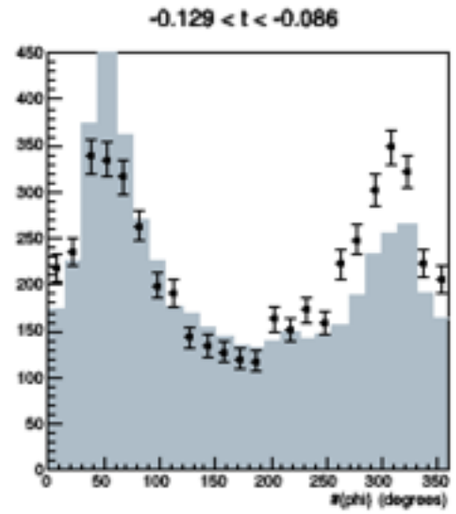
$$\frac{d^5\sigma_r^{data}}{dQ^2 dx_{Bj} dt d\phi d\varphi} = \frac{N_r^{data}}{N_r} \frac{d^5\sigma_r^{fit}}{dQ^2 dx_{Bj} dt d\phi d\varphi}$$

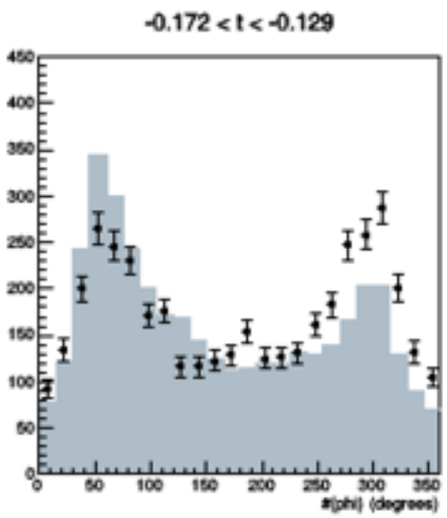
# 481— Unpol

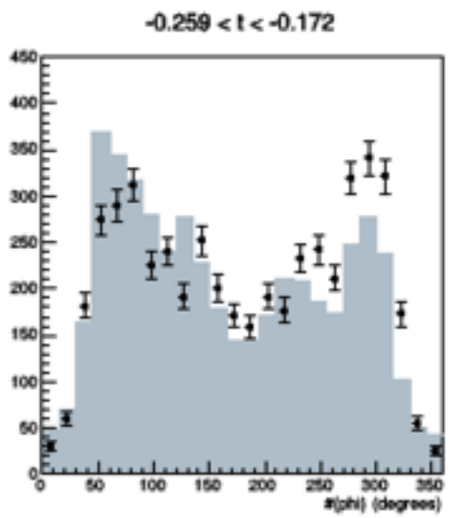
$N_+ + N_-$



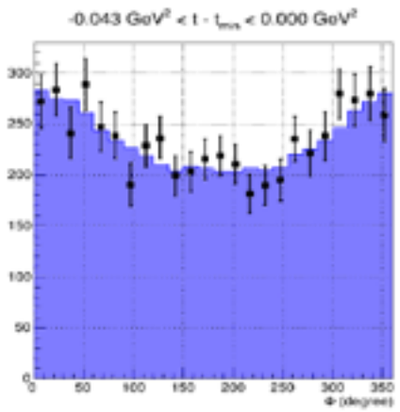



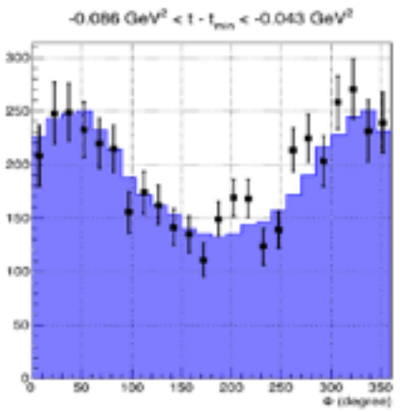



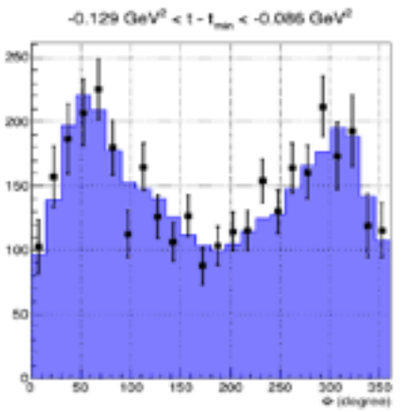



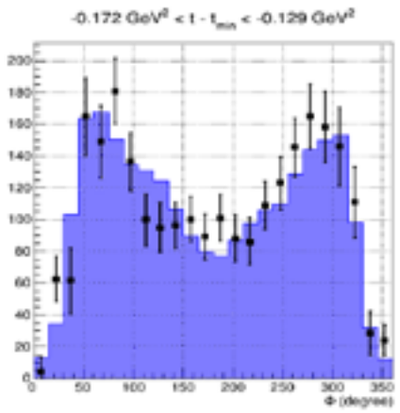



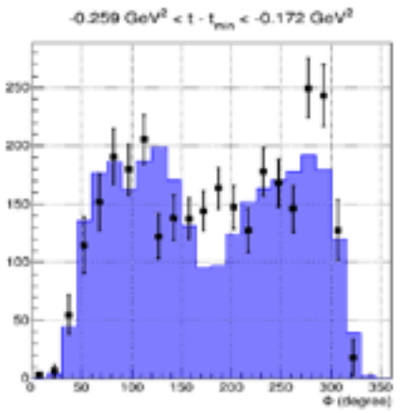

$$N_r = \sum_{v=0}^{\mathcal{V}} \sum_{n=0}^{N} \mathcal{K}_{rv}^{n} X_v^n$$

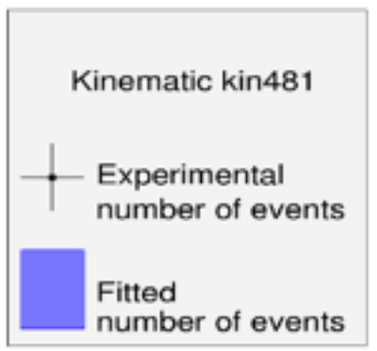


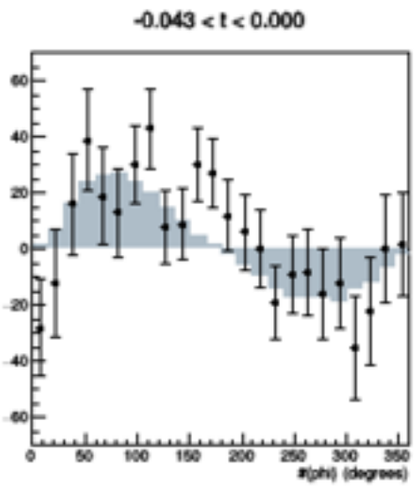



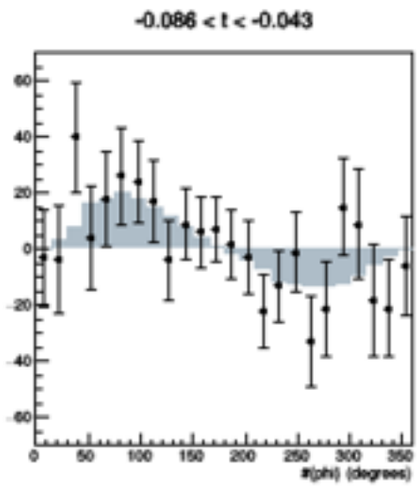



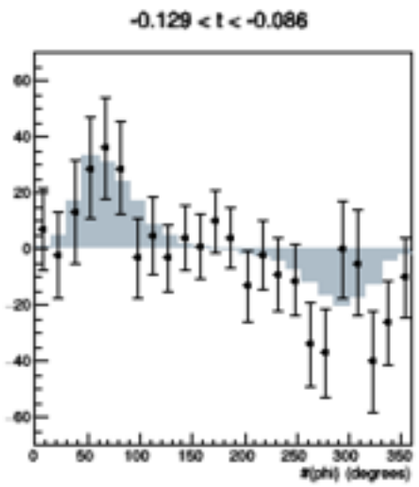



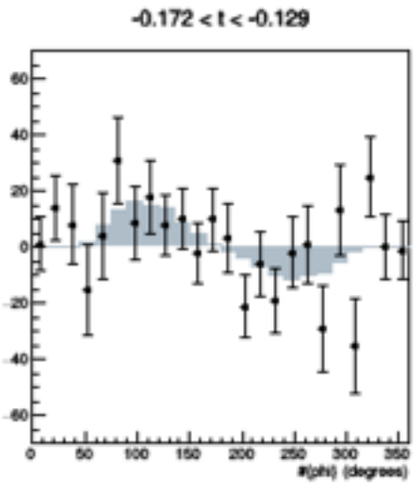



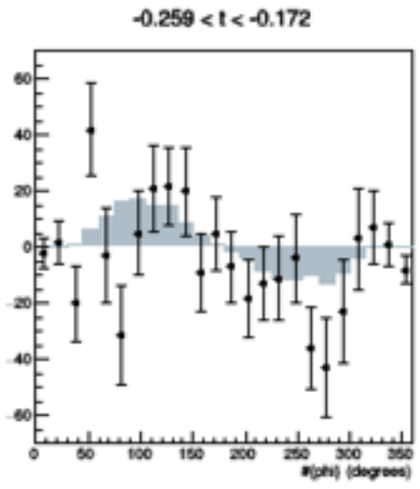
# $N_+$ - $N_-$ 481— Pol

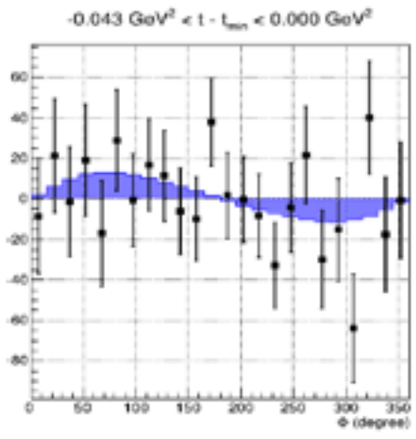

-0.043 < t < 0.000
#(phi) (degrees)

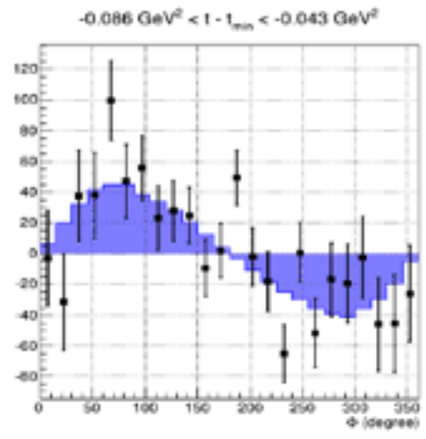

-0.086 < t < -0.043
#(phi) (degrees)

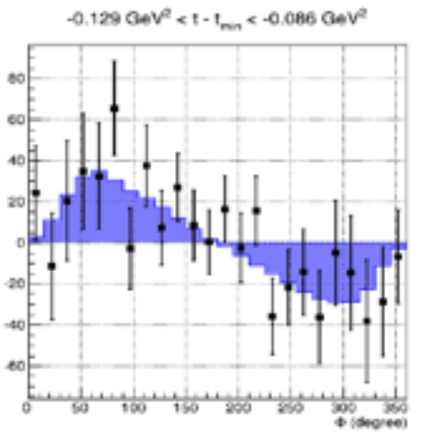

-0.129 < t < -0.086
#(phi) (degrees)

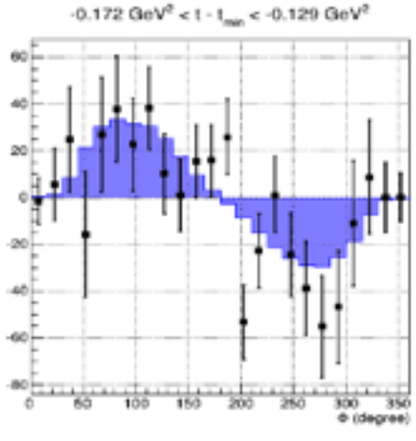

-0.172 < t < -0.129
#(phi) (degrees)

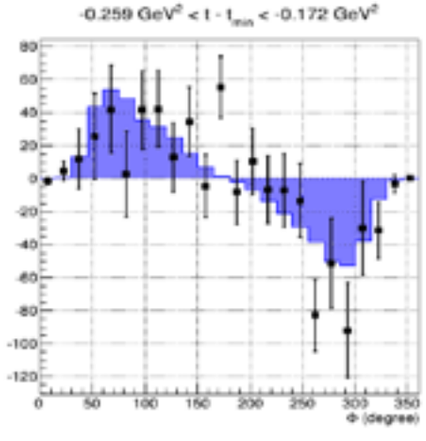

-0.259 < t < -0.172
#(phi) (degrees)

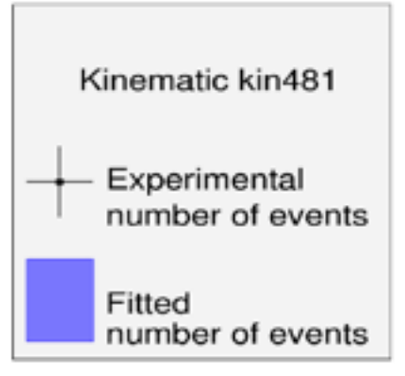

-0.043 GeV² < t - t_min < 0.000 GeV²
Φ (degree)


-0.086 GeV² < t - t_min < -0.043 GeV²
Φ (degree)


-0.129 GeV² < t - t_min < -0.086 GeV²
Φ (degree)


-0.172 GeV² < t - t_min < -0.129 GeV²
Φ (degree)


-0.259 GeV² < t - t_min < -0.172 GeV²
Φ (degree)


Kinematic kin481
Experimental number of events
Fitted number of events

# 481 Cross Section Extraction

$$\langle X_n \rangle_v = \sum_{n'=1}^{\mathcal{N}} \sum_{v'=1}^{\mathcal{V}} \left[A^{-1}\right]_{nv,n'v'} B_{n'v'}$$

v →

n ↓

C(DVCS)

| | 0 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| 0 | 36 | 2.367 | -9.14 | 34.93 | 2.473 |

40

Re C(F_++)

| | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|
| 0 | -7.207 | 35.28 | 3.132 | -5.414 | 35.8 |

-1.8

Re C(F_0+)

| | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|
| 0 | 3.161 | -3.291 | 34.69 | 2.992 | -2.949 |

-0.3

Im C(F_++)

| | 0 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| 0 | 0.5324 | 0.7556 | 0.2895 | 1.088 | 0.3759 |

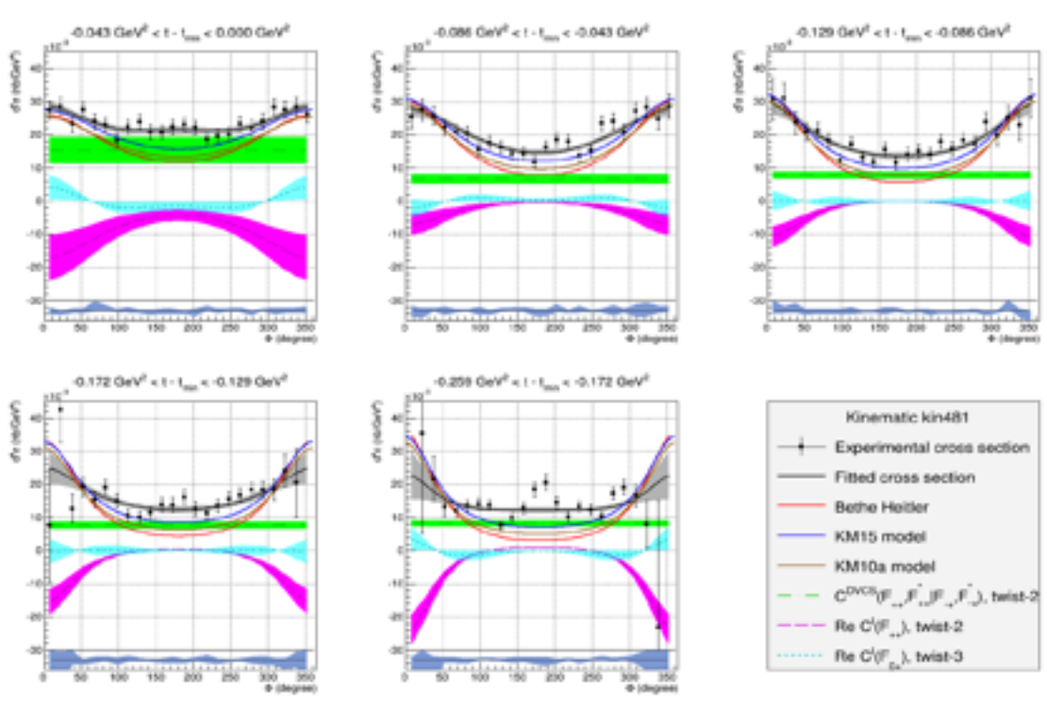
1.3

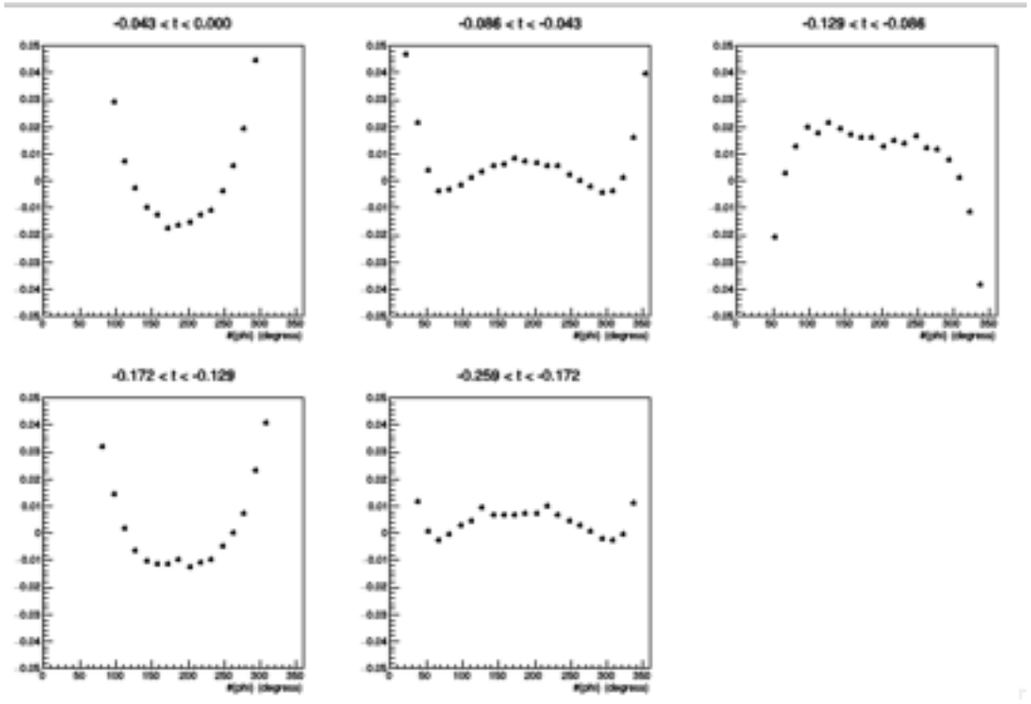
Im C(F_0+)

| | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|
| 0 | -1.638 | 0.1794 | 2.165 | 0.1462 | 0.8797 |

0.6

# Issues with cross section extraction

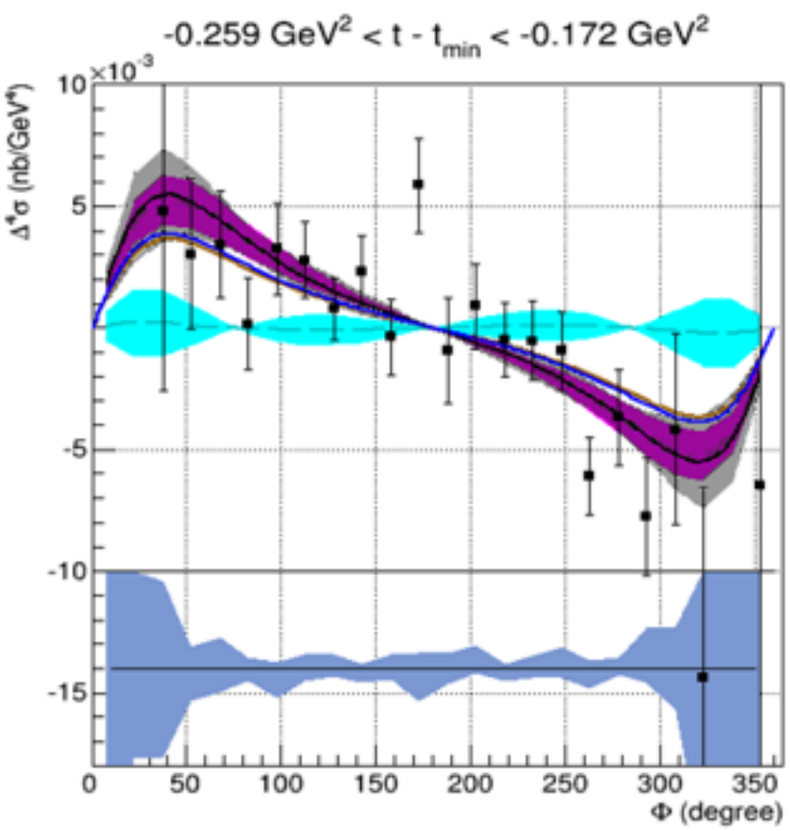


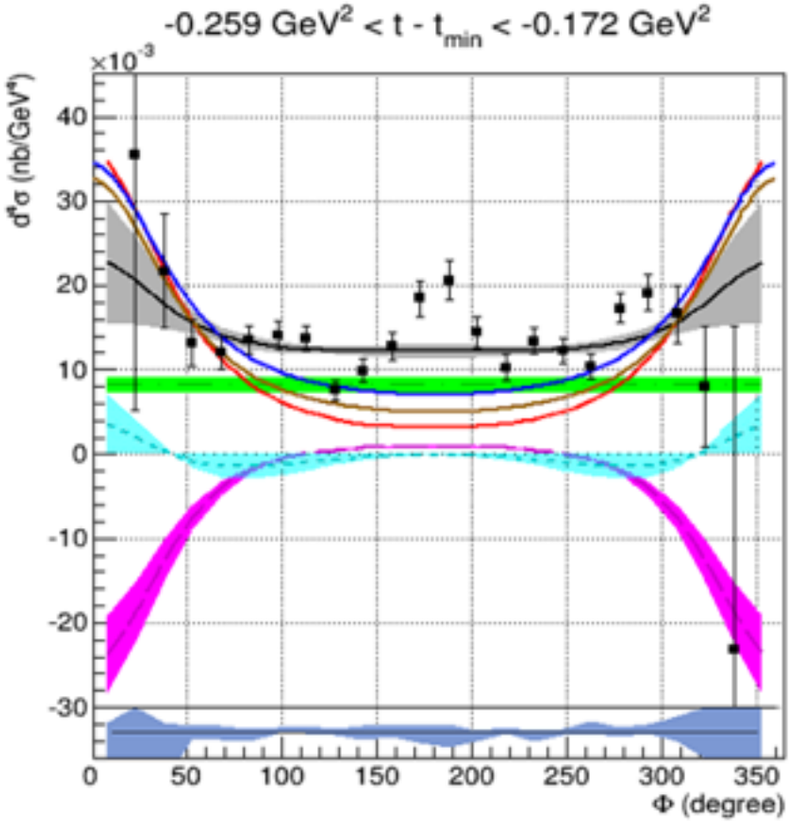

## Alexa

```
-0.000198384
-3.17849e-20
0.000318202
-0.000262726
0.00051497
-0.00839699
-0.0007653
0.0034352
0.000487679
0.000332934
0.000153336
-9.88665e-05
2.33218e-05
0
-2.34403e-05
-0.000139267
-0.00036001
-0.00153614
-0.000226375
-0.00037316
-0.000810513
0.00427978
0.000467538
0.000635409
-1.17216e-05
```

## Frederic



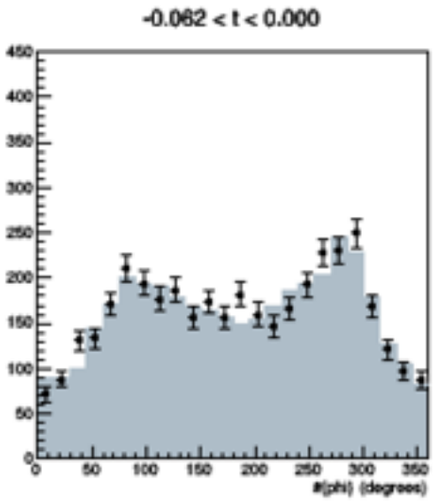

## Frederic

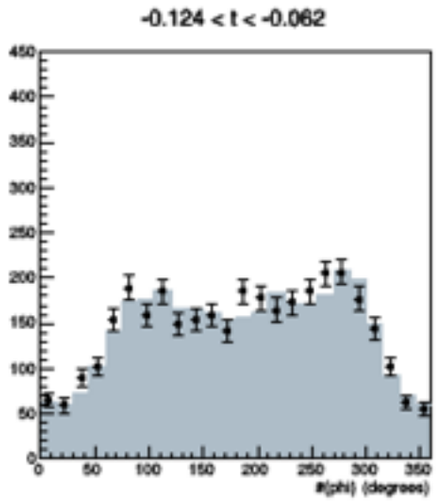


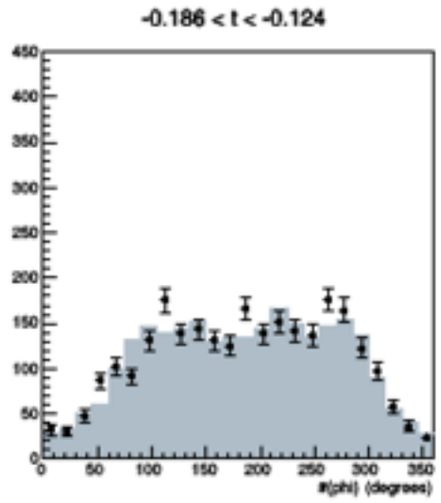

## Alexa

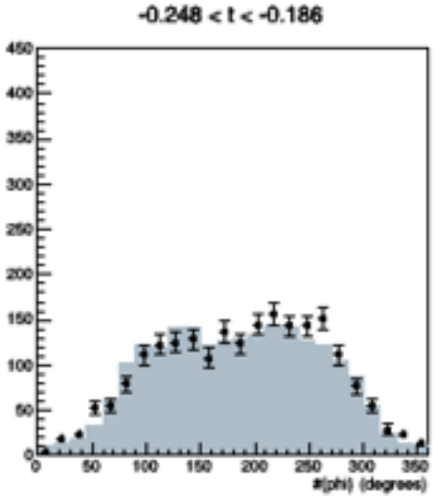
```
0.0888853
0.101935
0.135204
0.158673
0.0593896
0.0374961
0.020551
0.0196749
0.0118228
0.00824652
0.0094607
0.00782272
0.0119964
0.00755508
0.00726662
0.00685693
0.00746831
0.00763466
0.0102653
0.00754696
0.00602395
0.00527628
0.0047306
0.00477105
0.00549885
0.00746859
0.0199086
0.0529677
```

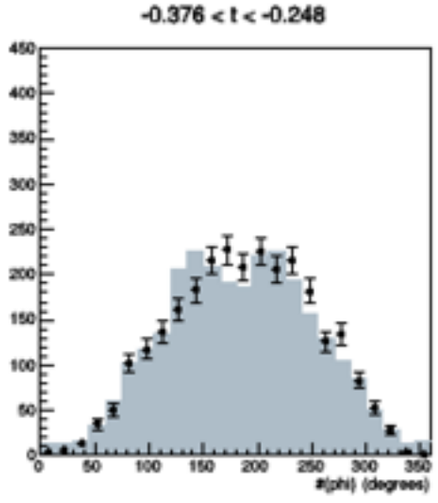
# $N_+$ + $N_-$ 482— Unpol

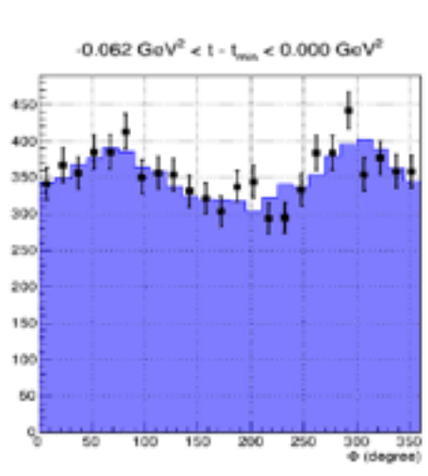

-0.062 < t < 0.000
#(phi) (degrees)

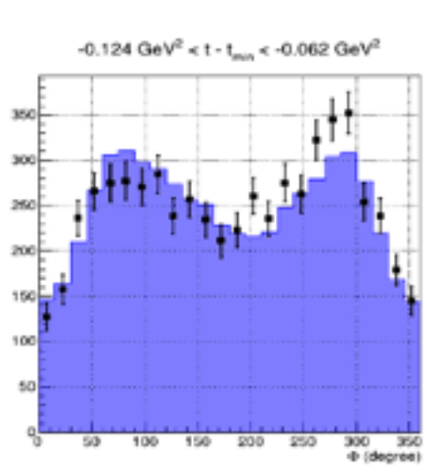

-0.124 < t < -0.062
#(phi) (degrees)

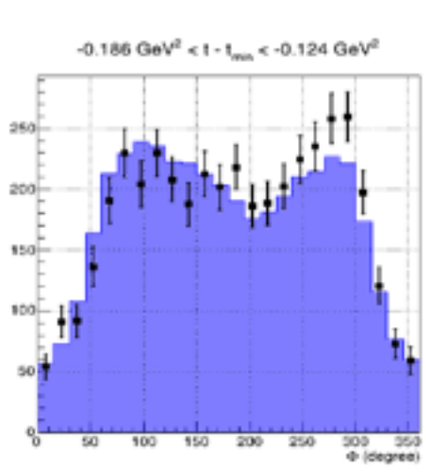

-0.186 < t < -0.124
#(phi) (degrees)

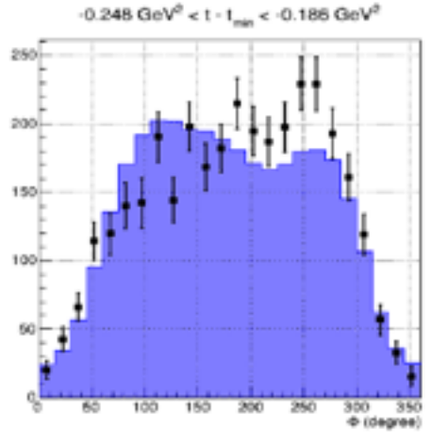

-0.248 < t < -0.186
#(phi) (degrees)

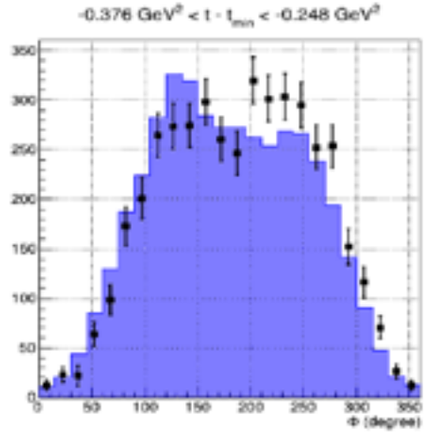

-0.376 < t < -0.248
#(phi) (degrees)

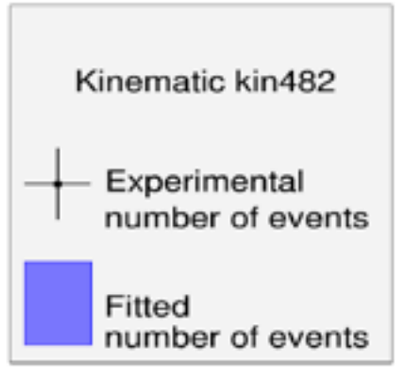

-0.062 GeV² < t - t_min < 0.000 GeV²
Φ (degree)


-0.124 GeV² < t - t_min < -0.062 GeV²
Φ (degree)

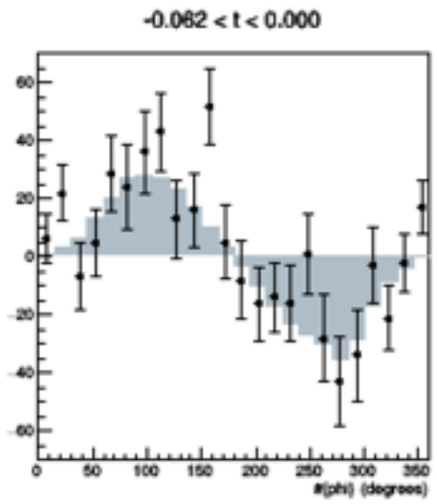

-0.186 GeV² < t - t_min < -0.124 GeV²
Φ (degree)

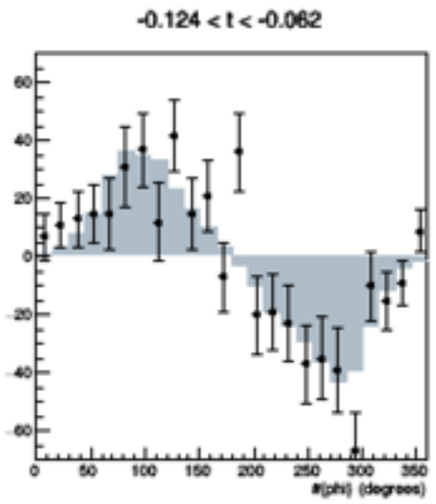

-0.248 GeV² < t - t_min < -0.186 GeV²
Φ (degree)

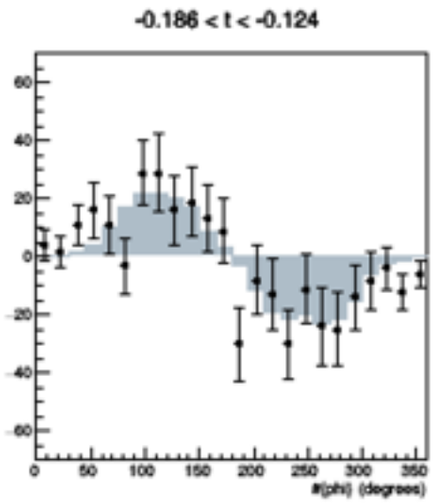

-0.376 GeV² < t - t_min < -0.248 GeV²
Φ (degree)

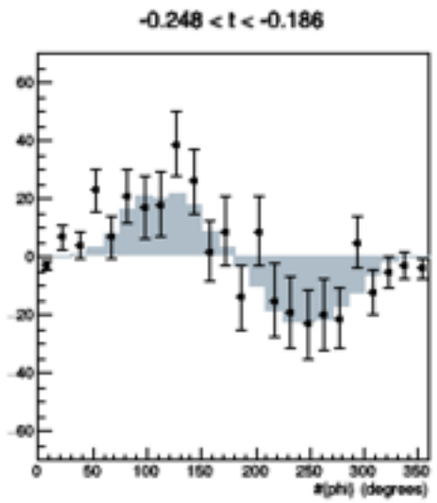

Kinematic kin482
Experimental number of events
Fitted number of events

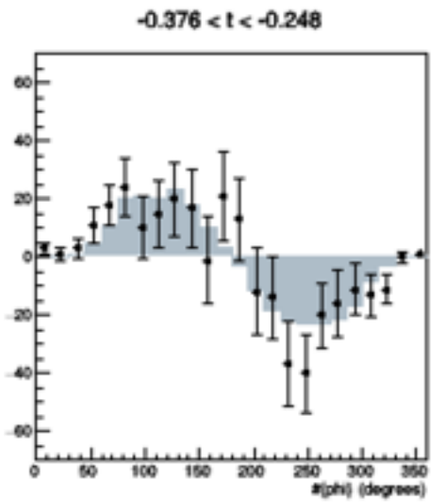
# $N_+$ - $N_-$ 482— Pol

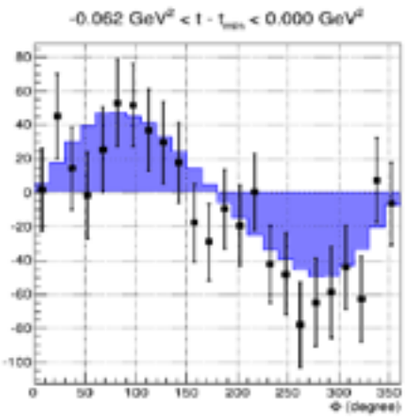

-0.062 < t < 0.000
#(phi) (degrees)

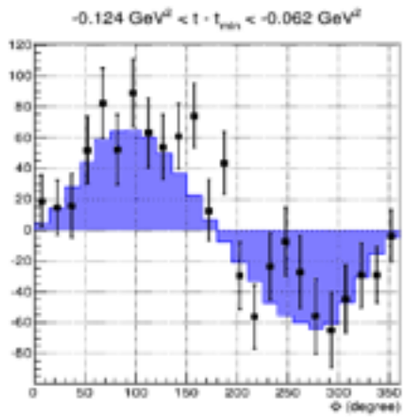

-0.124 < t < -0.062
#(phi) (degrees)

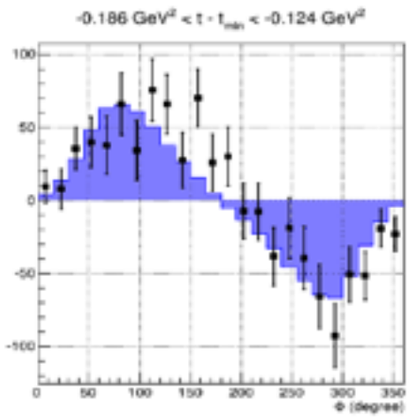

-0.186 < t < -0.124
#(phi) (degrees)

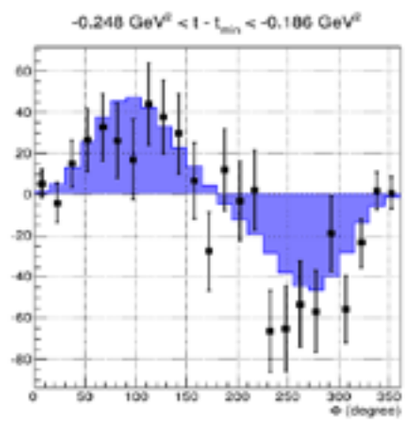

-0.248 < t < -0.186
#(phi) (degrees)

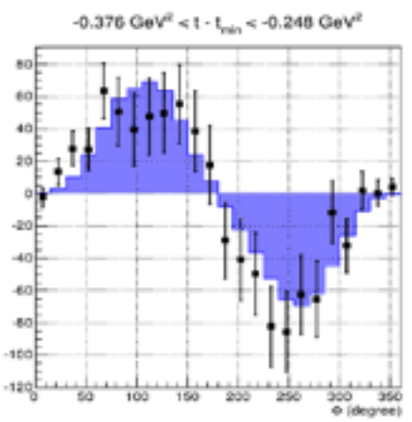

-0.376 < t < -0.248
#(phi) (degrees)

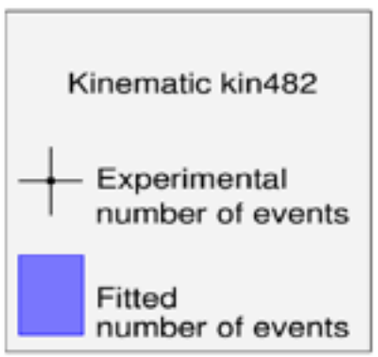

-0.062 GeV² < t - t_min < 0.000 GeV²
Φ (degree)


-0.124 GeV² < t - t_min < -0.062 GeV²
Φ (degree)

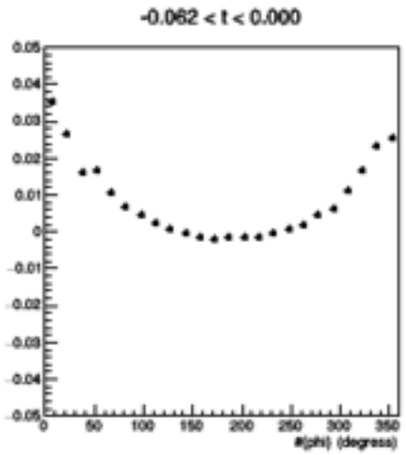

-0.186 GeV² < t - t_min < -0.124 GeV²
Φ (degree)

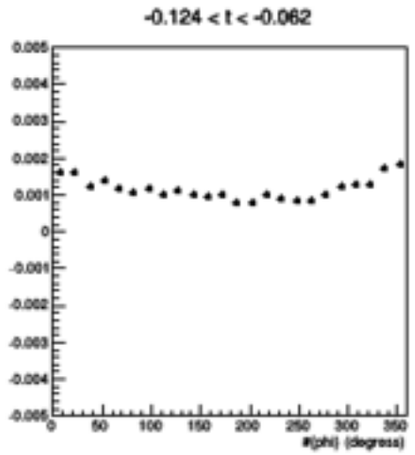

-0.248 GeV² < t - t_min < -0.186 GeV²
Φ (degree)

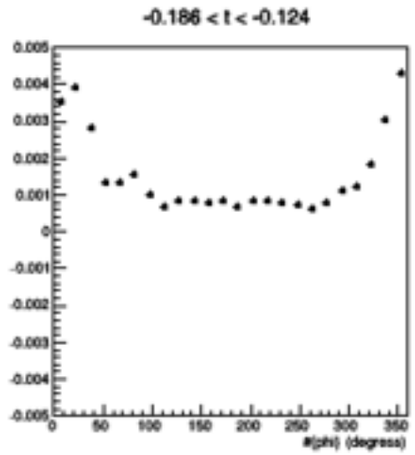

-0.376 GeV² < t - t_min < -0.248 GeV²
Φ (degree)

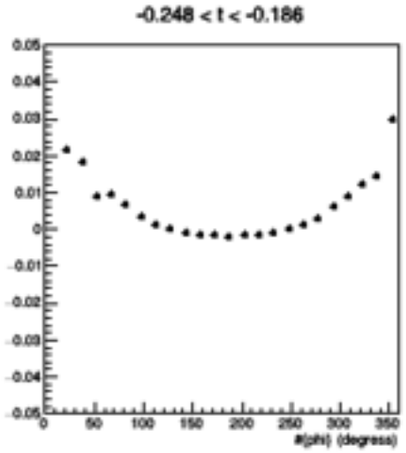

Kinematic kin482
Experimental number of events
Fitted number of events

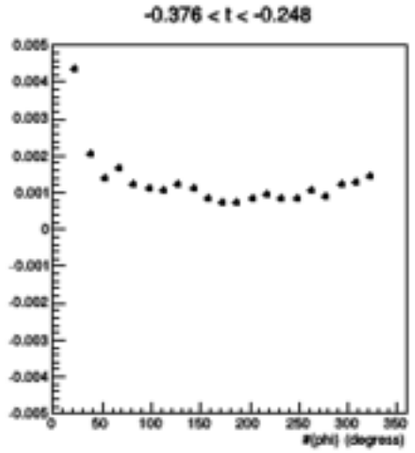
# 482 Cross Section Extraction

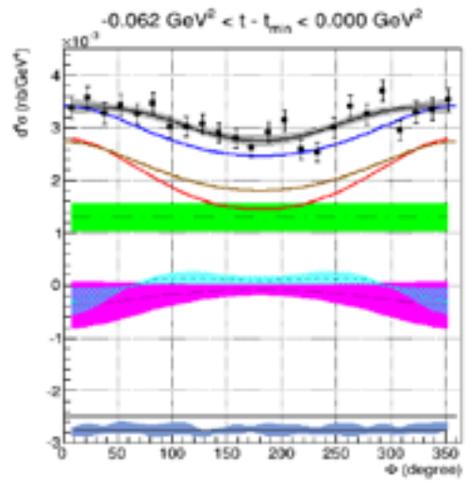


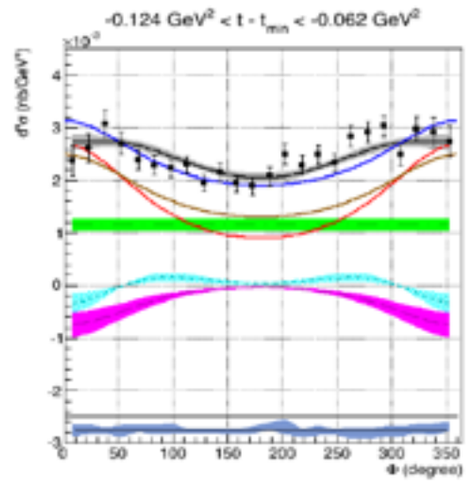



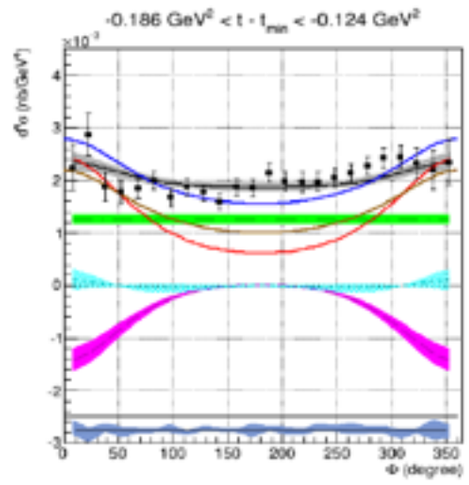



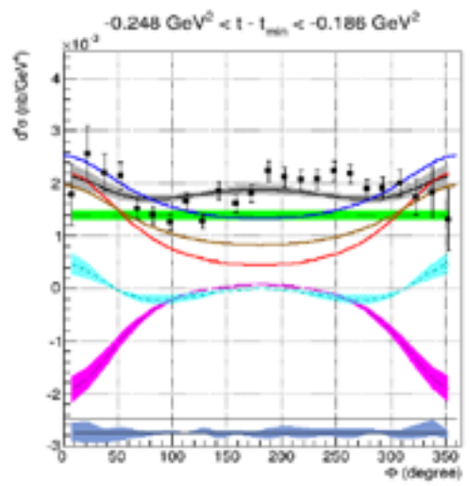



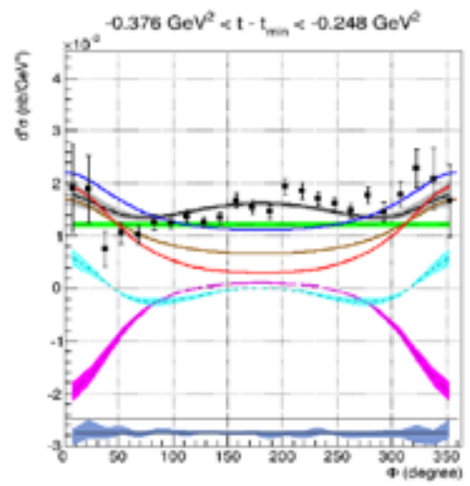



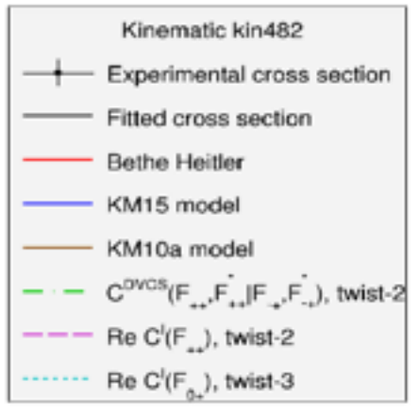



# 482 Cross Section Extraction

$$\frac{d^4\sigma}{dQ^2 dx_B dt d\phi} = \sum_{n=0}^{N} F_n(E, Q^2, x_B, t, \phi) X^n$$

C(DVCS)

| | 0 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| 0 | 16.84 | 0.855 | 1.611 | 16.43 | 0.687 |

Re C(F_++)

| | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|
| 0 | 1.225 | 15.21 | 0.5146 | 0.9485 | 15.36 |

-0.9

Re C(F_0+)

| | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|
| 0 | 0.1221 | 1.291 | 12.99 | 0.05023 | -0.1473 |

0

Im C(F_++)

| | 0 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| 0 | 0.485 | 0.876 | 0.6332 | -0.208 | 0.3404 |

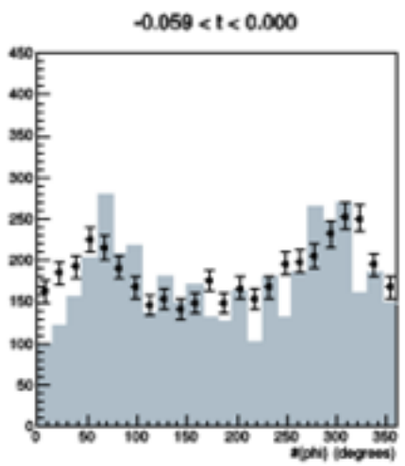
1.5

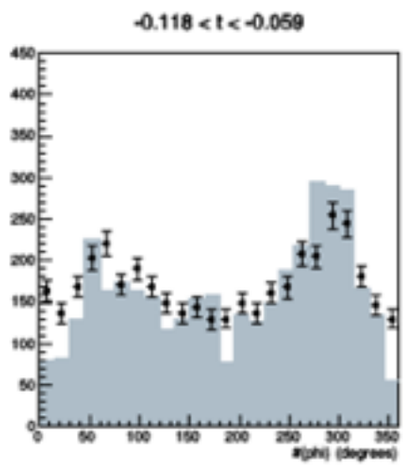
Im C(F_0+)

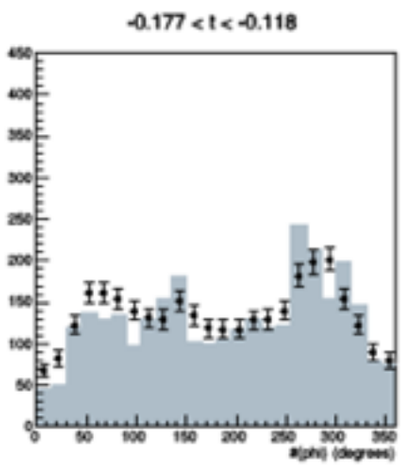
| | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|
| 0 | 1.564 | 0.3842 | 1.843 | 0.3448 | 0.3903 |

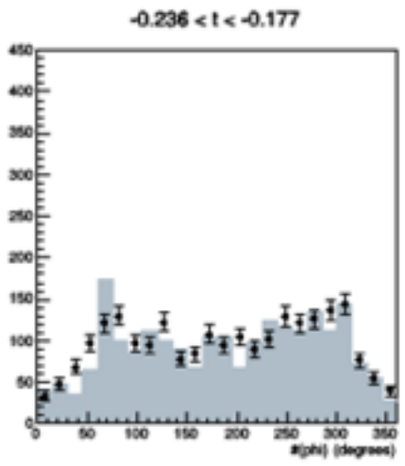
0.3

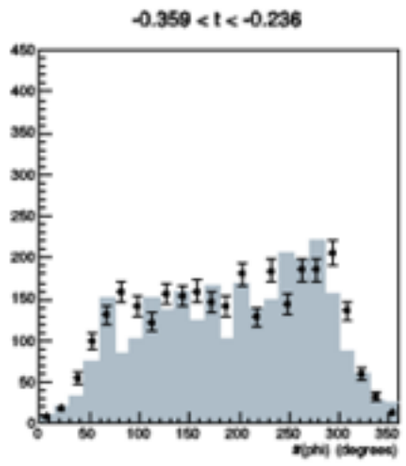
# $N_+ + N_-$ 483— Unpol



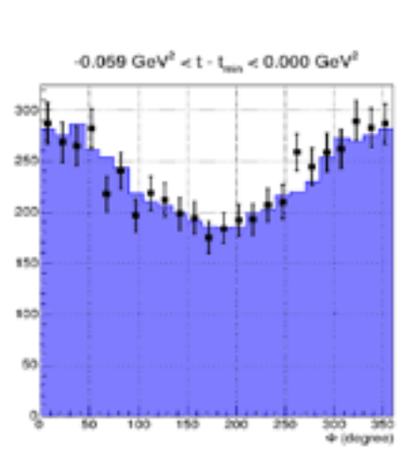



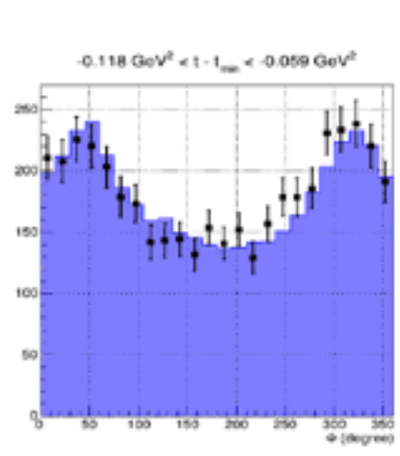



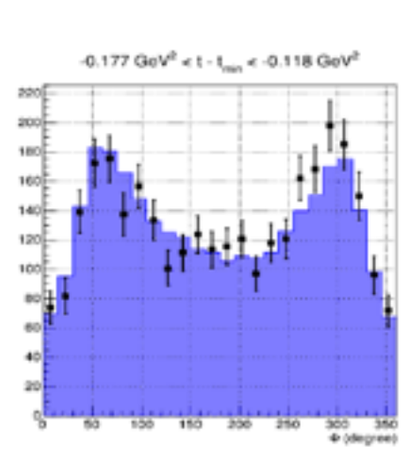



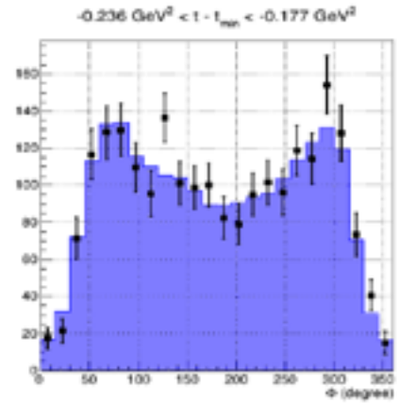



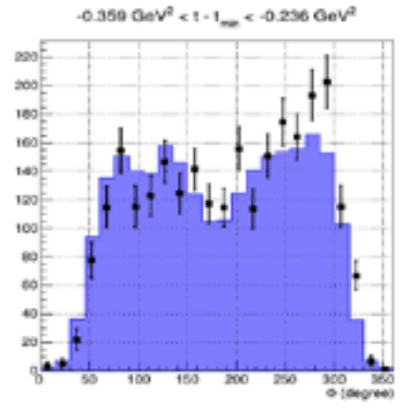

Need to re-visit this Kin setting

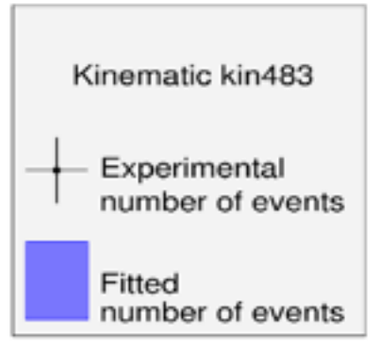


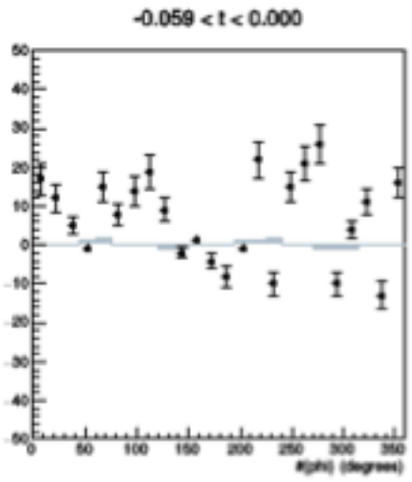



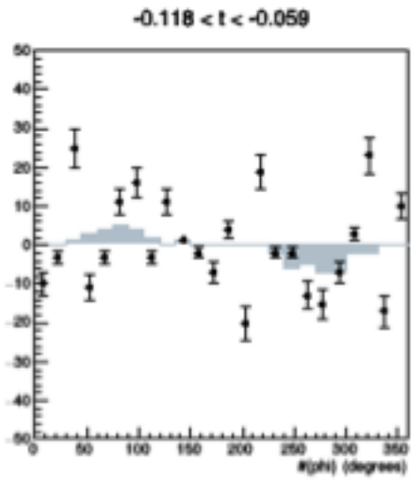



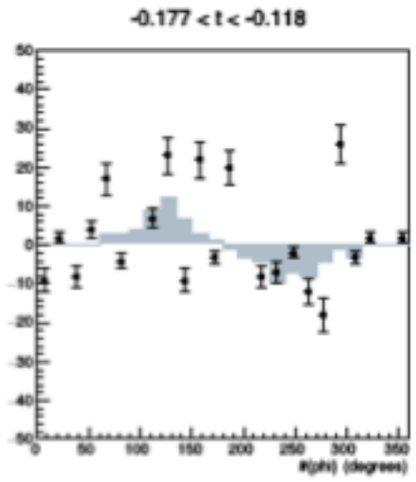



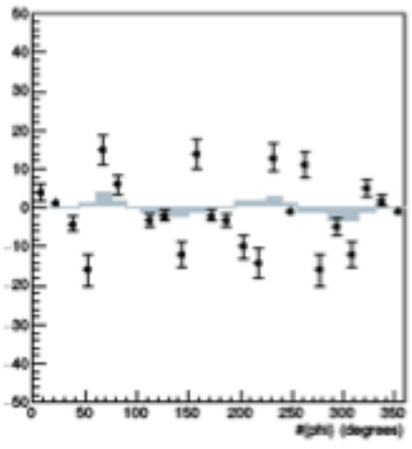



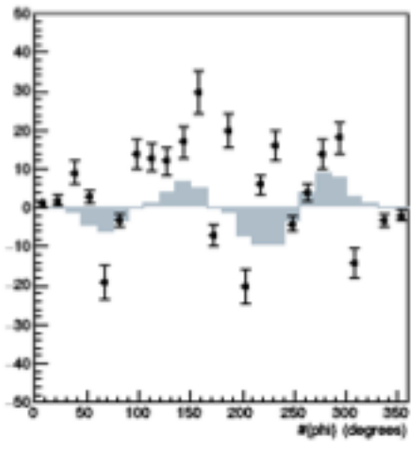
# $N_+$ - $N_-$ 483— Pol

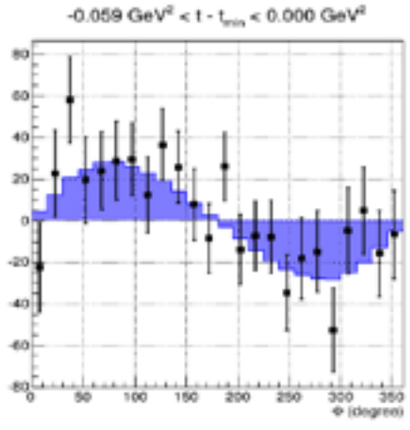

-0.059 < t < 0.000
#(phi) (degrees)

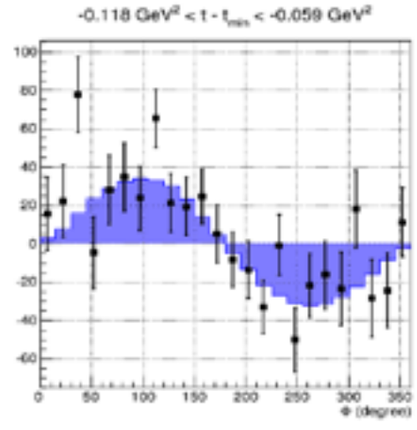

-0.118 < t < -0.059
#(phi) (degrees)

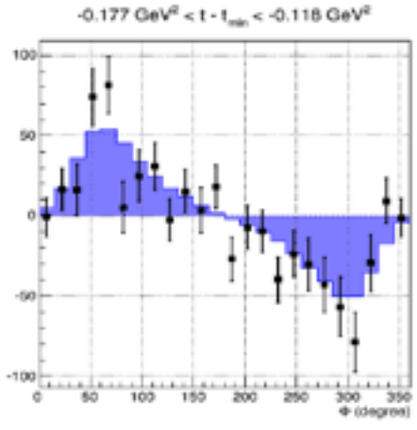

-0.177 < t < -0.118
#(phi) (degrees)

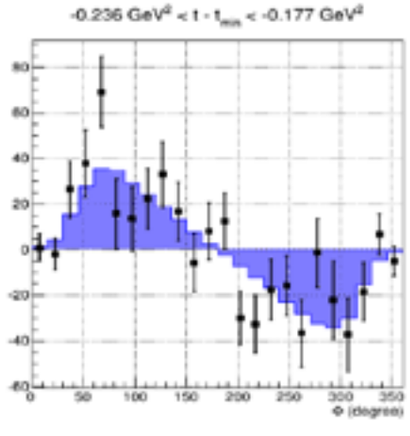

-0.236 < t < -0.177
#(phi) (degrees)

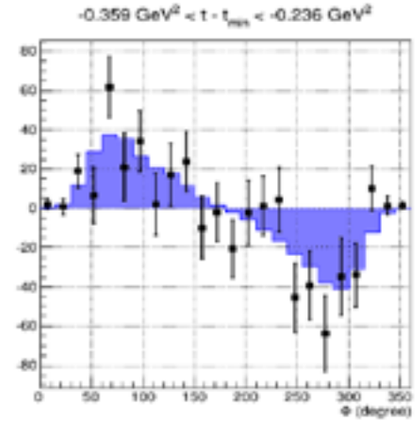

-0.359 < t < -0.236
#(phi) (degrees)

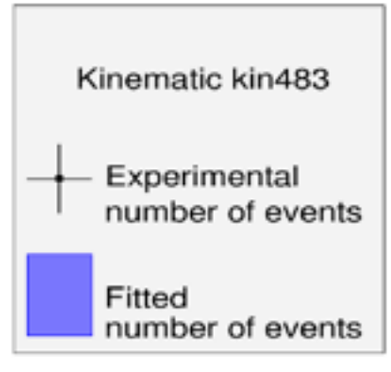

-0.059 GeV² < t - t_min < 0.000 GeV²
Φ (degrees)


-0.118 GeV² < t - t_min < -0.059 GeV²
Φ (degrees)


-0.177 GeV² < t - t_min < -0.118 GeV²
Φ (degrees)


-0.236 GeV² < t - t_min < -0.177 GeV²
Φ (degrees)


-0.359 GeV² < t - t_min < -0.236 GeV²
Φ (degrees)


Kinematic kin483
Experimental number of events
Fitted number of events

# 483 Cross Section Extraction

C(DVCS)

| | 0 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| 0 | 3.553 | -0.07747 | 1.084 | 1.656 | -0.05046 |

16

Re C(F_++)

| | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|
| 0 | 0.649 | 0.4889 | -0.009828 | 0.3354 | 0.2329 |

-0.5

Re C(F_0+)

| | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|
| 0 | -0.01913 | 0.1313 | 0.02767 | 0.0003512 | 0.02073 |

-0.05

Im C(F_++)

| | 0 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| 0 | -0.009549 | -0.01371 | 0.02411 | 0.1542 | 0.00744 |

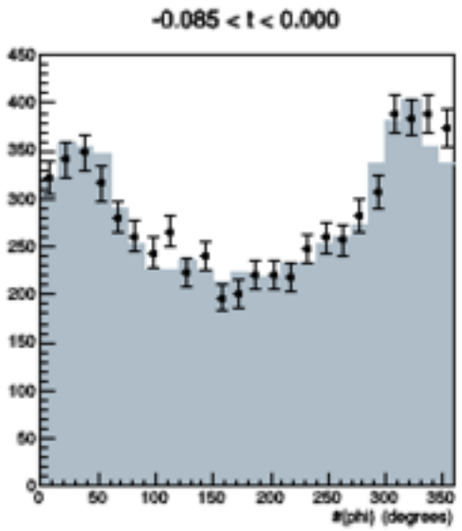
1.4

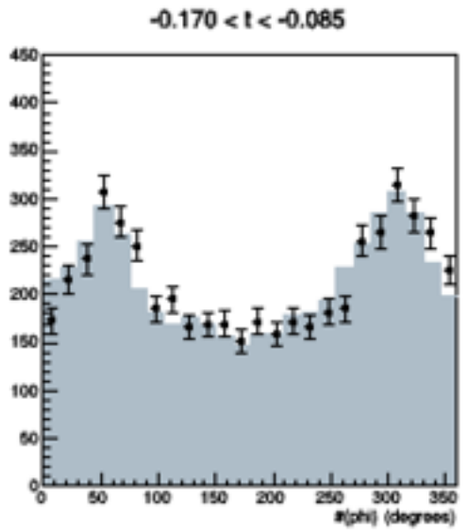
Im C(F_0+)

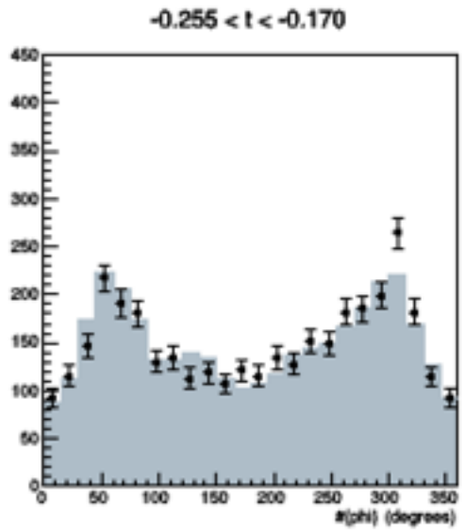
| | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|
| 0 | -0.1357 | -0.00367 | -0.0418 | 0.003614 | -0.09345 |

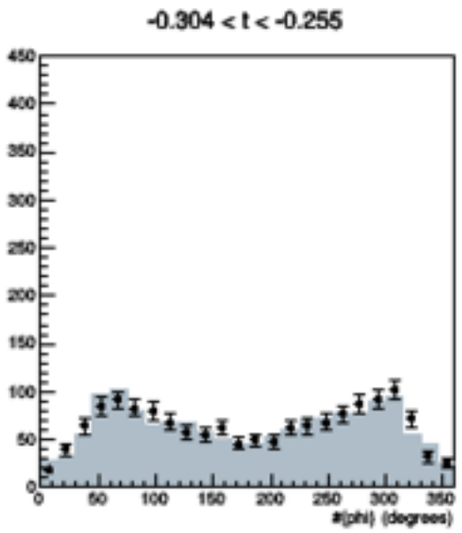
0.05

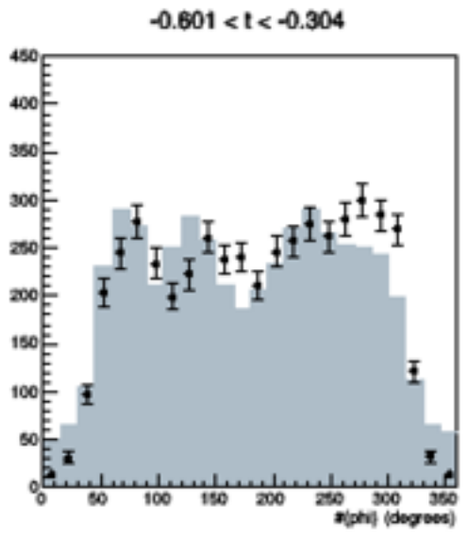
# $N_+ + N_-$ 484— Unpol

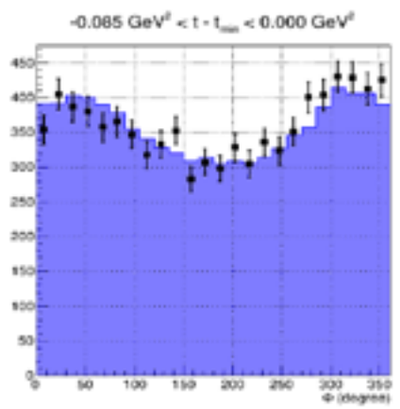

-0.085 < t < 0.000
#(phi) (degrees)

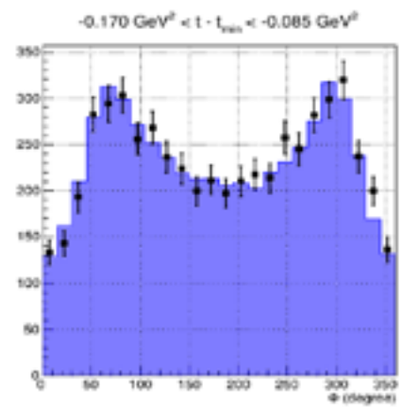

-0.170 < t < -0.085
#(phi) (degrees)

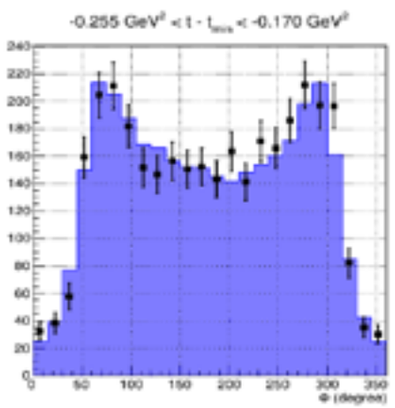

-0.255 < t < -0.170
#(phi) (degrees)

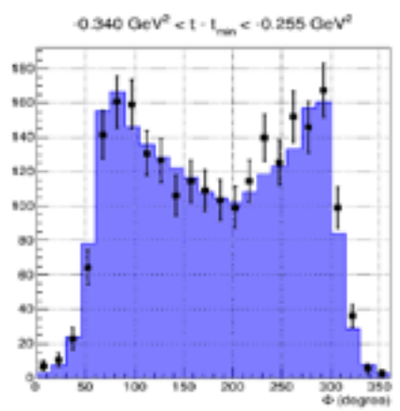

-0.304 < t < -0.255
#(phi) (degrees)

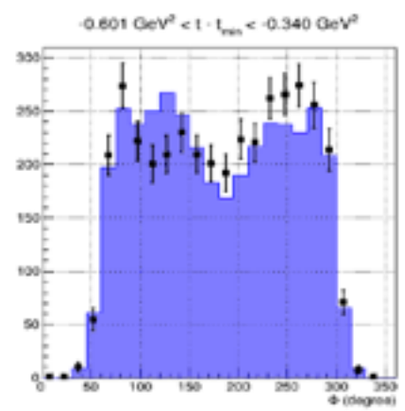

-0.601 < t < -0.304
#(phi) (degrees)

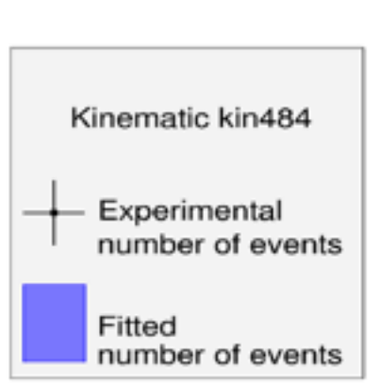

-0.085 GeV² < t - t_min < 0.000 GeV²
Φ (degrees)


-0.170 GeV² < t - t_min < -0.085 GeV²
Φ (degrees)

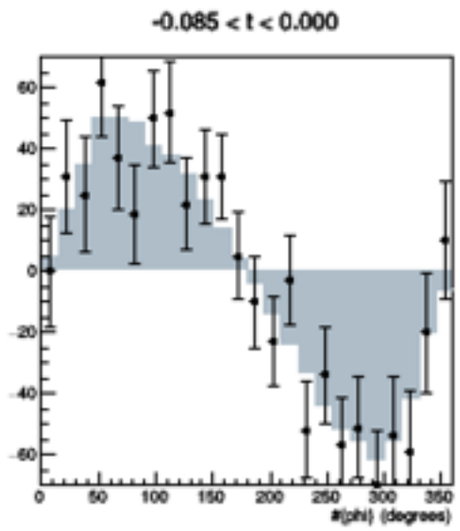

-0.255 GeV² < t - t_min < -0.170 GeV²
Φ (degrees)

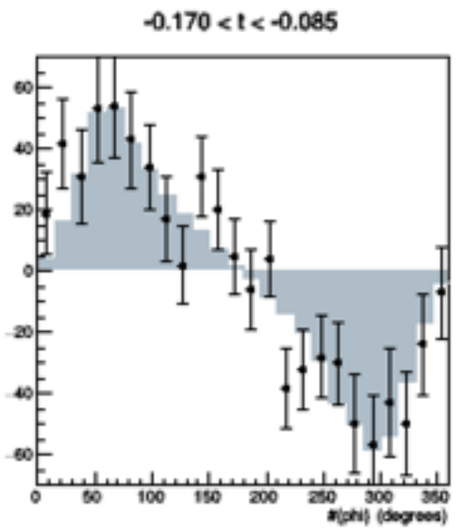

-0.340 GeV² < t - t_min < -0.255 GeV²
Φ (degrees)

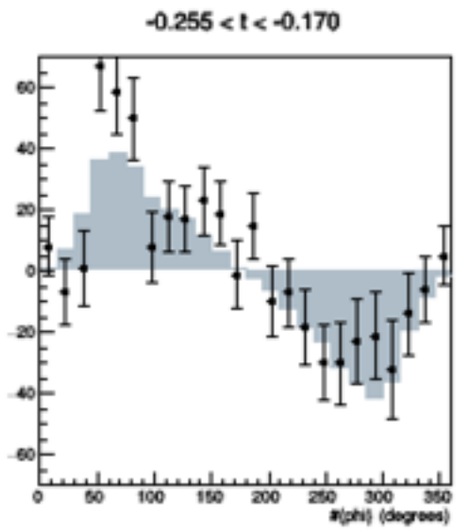

-0.601 GeV² < t - t_min < -0.340 GeV²
Φ (degrees)

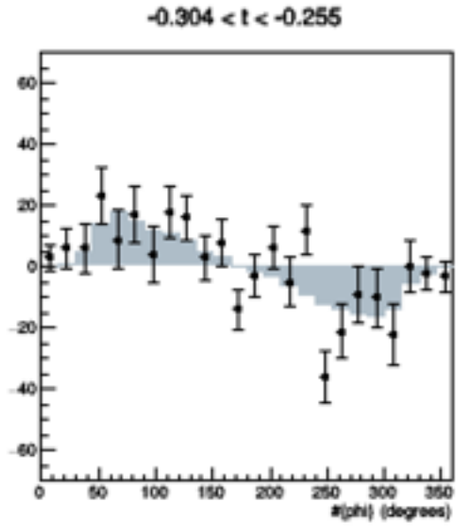

Kinematic kin484
Experimental number of events
Fitted number of events

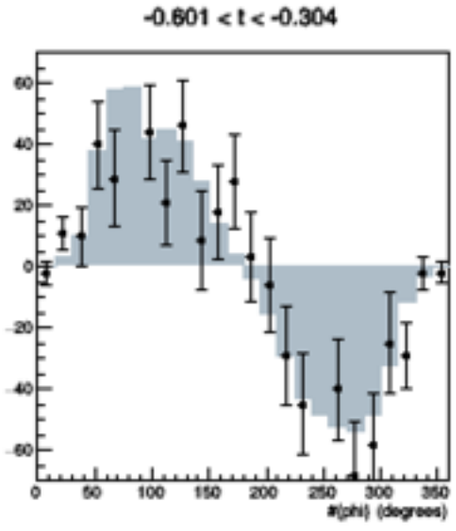
# $N_+$ - $N_-$ 484— Pol

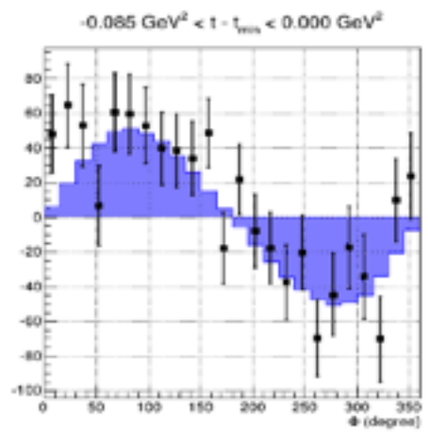

-0.085 < t < 0.000
#(phi) (degrees)

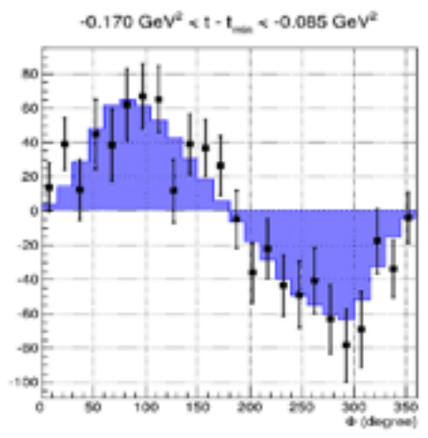

-0.170 < t < -0.085
#(phi) (degrees)

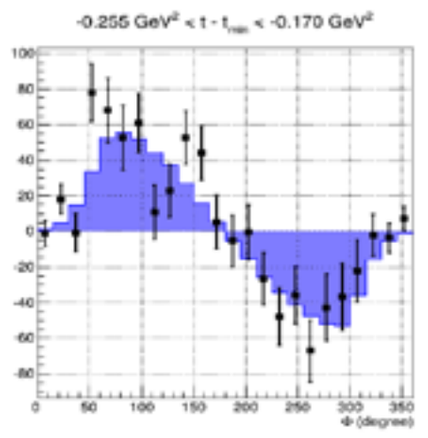

-0.255 < t < -0.170
#(phi) (degrees)

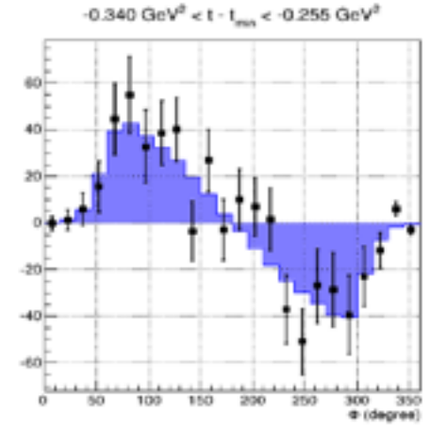

-0.304 < t < -0.255
#(phi) (degrees)

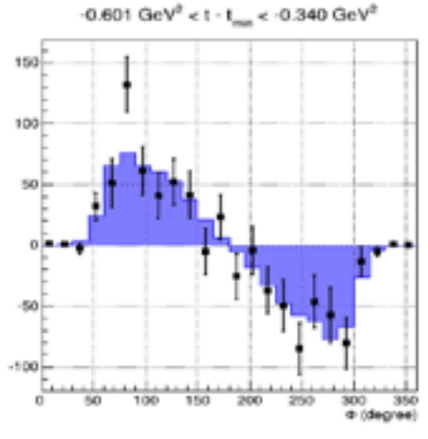

-0.601 < t < -0.304
#(phi) (degrees)

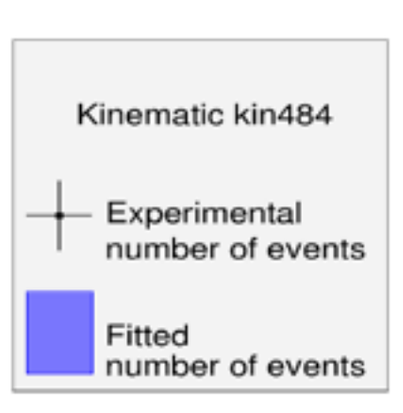

-0.085 GeV² < t - t_min < 0.000 GeV²
Φ (degree)


-0.170 GeV² < t - t_min < -0.085 GeV²
Φ (degree)


-0.255 GeV² < t - t_min < -0.170 GeV²
Φ (degree)

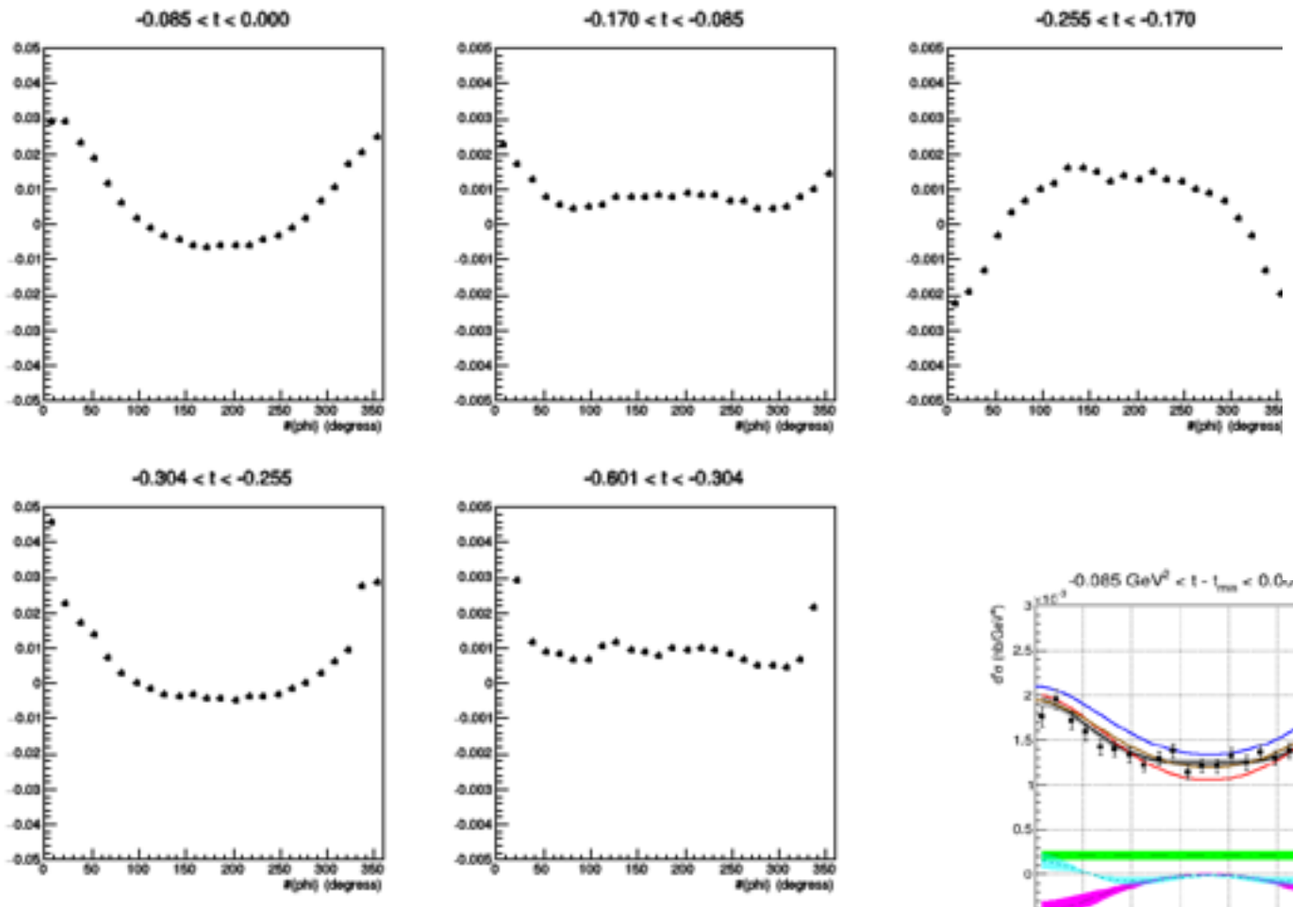

-0.340 GeV² < t - t_min < -0.255 GeV²
Φ (degree)

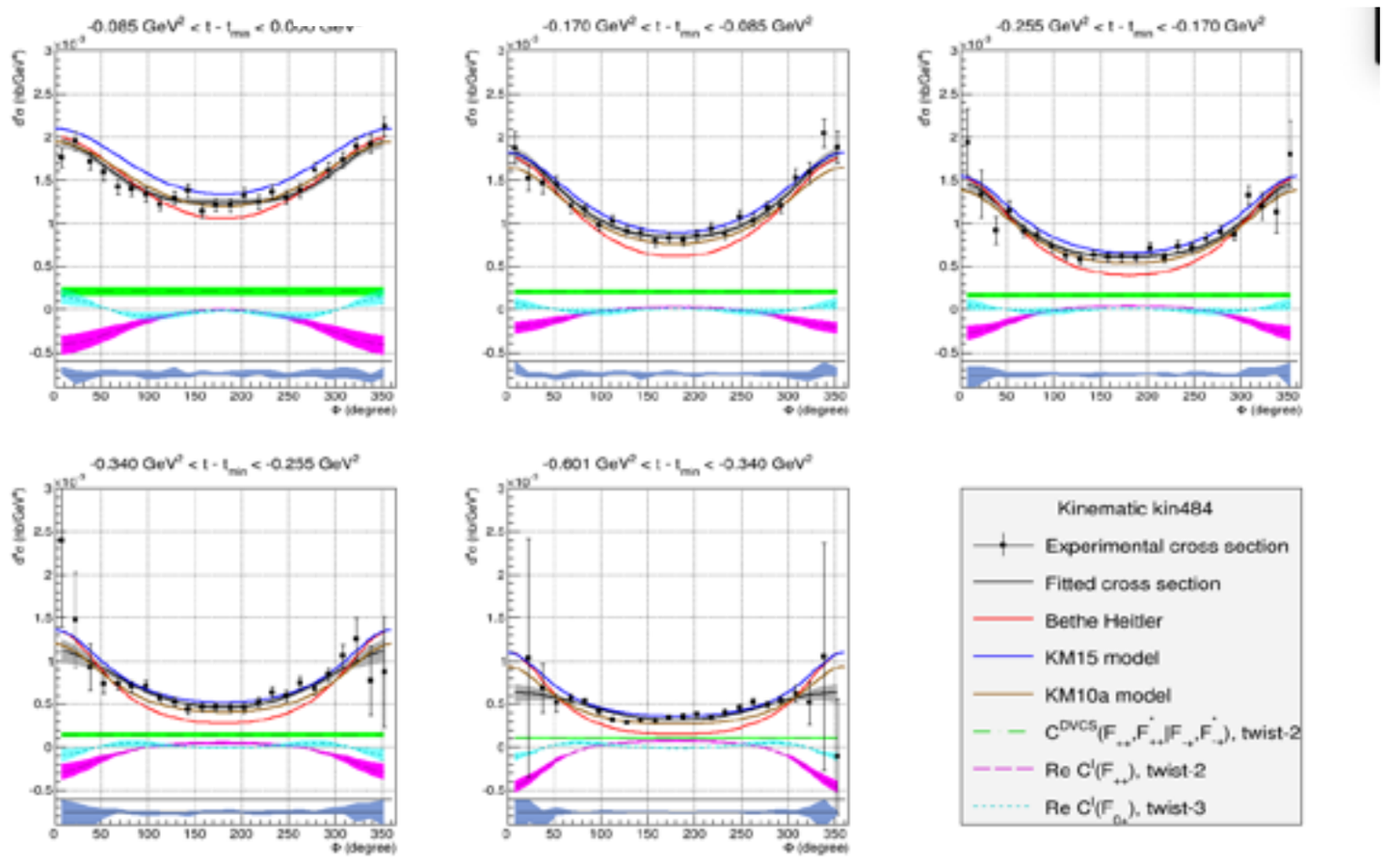

-0.601 GeV² < t - t_min < -0.340 GeV²
Φ (degree)


Kinematic kin484
Experimental number of events
Fitted number of events

# 484— Cross Sections

$$\frac{d^4\sigma}{dQ^2 dx_B dt d\phi} = \sum_{n=0}^{N} F_n(E, Q^2, x_B, t, \phi) X^n$$



# 484 Cross Section Extraction

C(DVCS)

| | 0 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| 0 | 50.8 | 1.397 | -3.006 | 42.9 | 1.493 |

12

Re C(F_++)

| | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|
| 0 | -0.3996 | 37.95 | 1.443 | 0.3755 | 37.95 |

-0.5

Re C(F_0+)

| | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|
| 0 | 1.629 | 0.5721 | 27.84 | 1.185 | 0.5976 |

-0.2

Im C(F_++)

| | 0 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| 0 | 0.7992 | 0.2352 | 0.6787 | -1.64 | 0.5558 |

0.3

Im C(F_0+)

| | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|
| 0 | -0.6038 | 0.537 | -0.2106 | 0.435 | 0.0033 |

1.4

# Conclusion:

CFFs and extracted cross sections mostly have the correct order of magnitude, but do not agree with Frederic's results.

Plan to triple check all of my analysis cuts.

Plan to triple check my fitting procedure for any coding errors.