PRECISION MØLLER POLARIMETRY IN HALL A

JANUARY 16TH, 2019

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TEMPLE UNIVERSITY

PRECISION MØLLER POLARIMETRY

- **INTRODUCTION**
  - MØLLER SCATTERING
  - HISTORY OF POLARIMETER IN HALL A
  - FUTURE EXPERIMENTS AND REQUIREMENTS
  - NEW TARGET MOTION SYSTEM
  - RECENTS RESULTS
- **ERROR ANALYSIS**
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- **INTRODUCTION**
  - **MØLLER SCATTERING**
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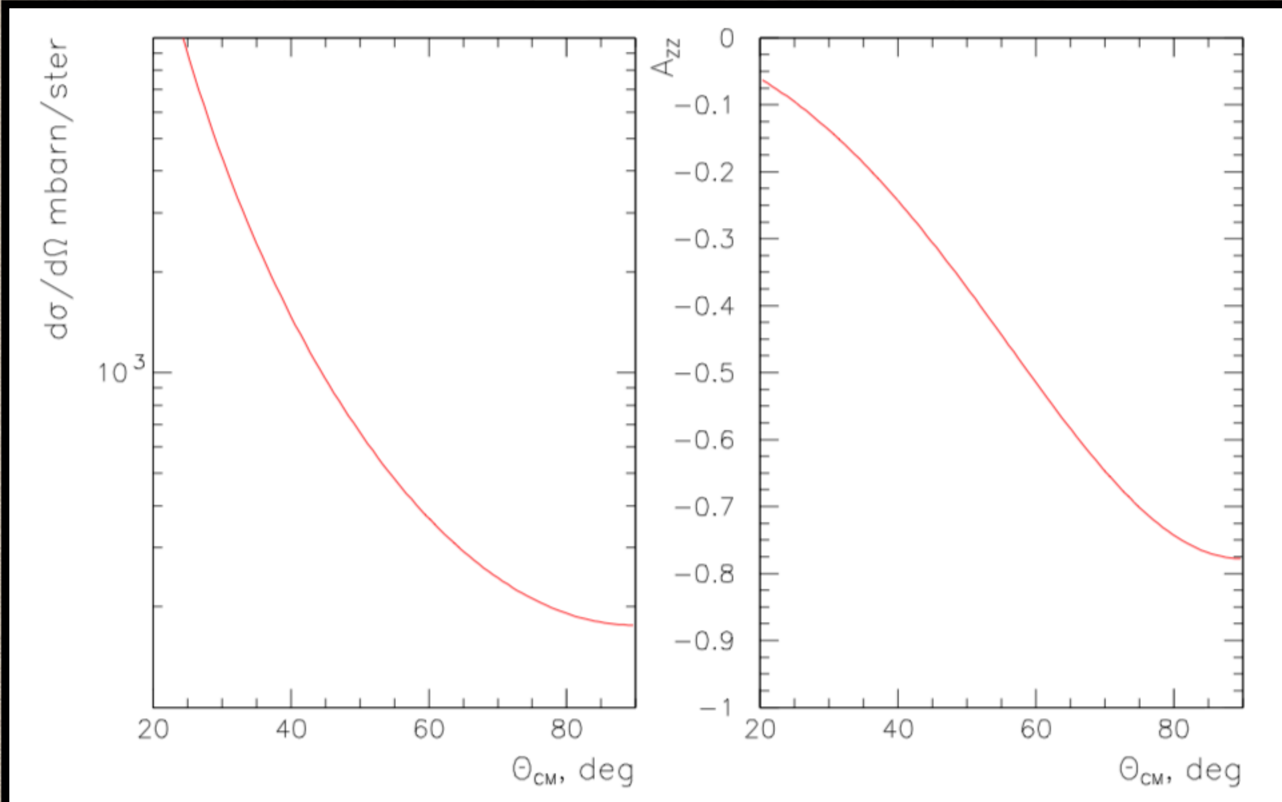
  - **NEW TARGET MOTION SYSTEM**
  - **RECENTS RESULTS**

Møller Scattering

Differential Cross Section

Analyzing Power (Azz)



Scattering Angle

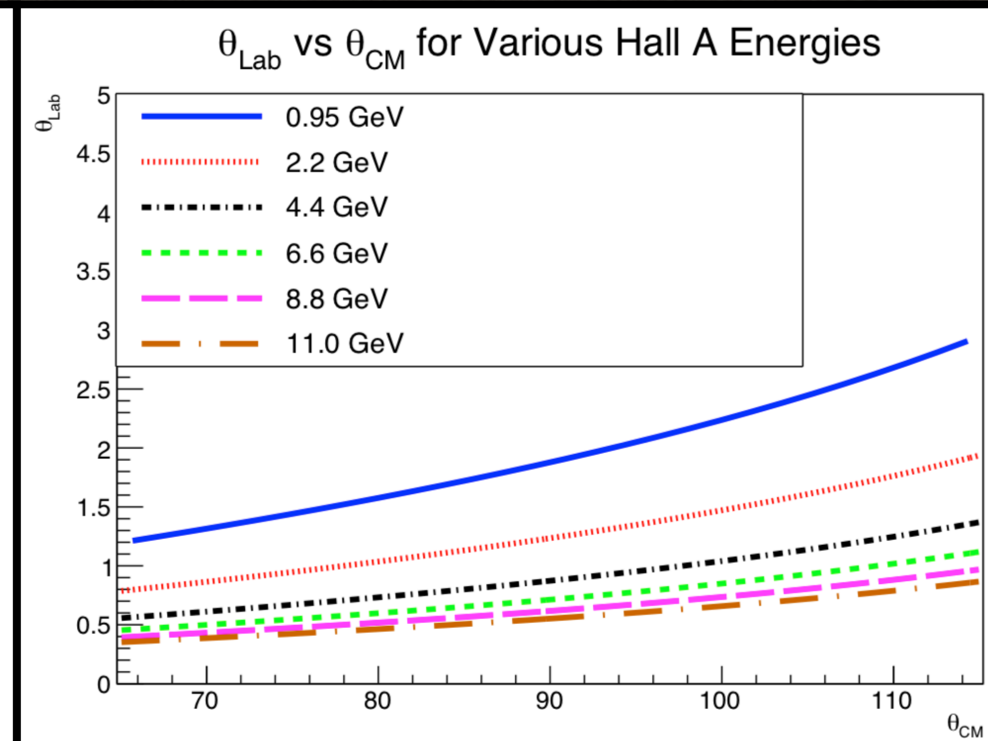


Figure 3.2: The Møller scattering angle in the lab frame vs CM frame

Large at 90°CM = -7/9

$$\mathcal{A}_{beam} = \frac{N_{\uparrow\uparrow} - N_{\uparrow\downarrow}}{N_{\uparrow\uparrow} + N_{\uparrow\downarrow}} = \mathcal{A}_{zz}(\theta_{CM}) \mathcal{P}_z^{Beam} \mathcal{P}^{Foil}$$

$$\mathcal{A}_{zz}(\theta_{CM}) = \frac{-\sin^2\theta_{CM}(8 - \sin^2\theta_{CM})}{(4 - \sin^2\theta_{CM})^2}$$

PRECISION MØLLER POLARIMETRY

Beam Polarization

Measured Asymmetry

$$\mathcal{P}_z^{beam} = \frac{A_{beam}}{\mathcal{P}^{Foil} \langle A_{zz} \rangle}$$

Target Polarization from **Theory**

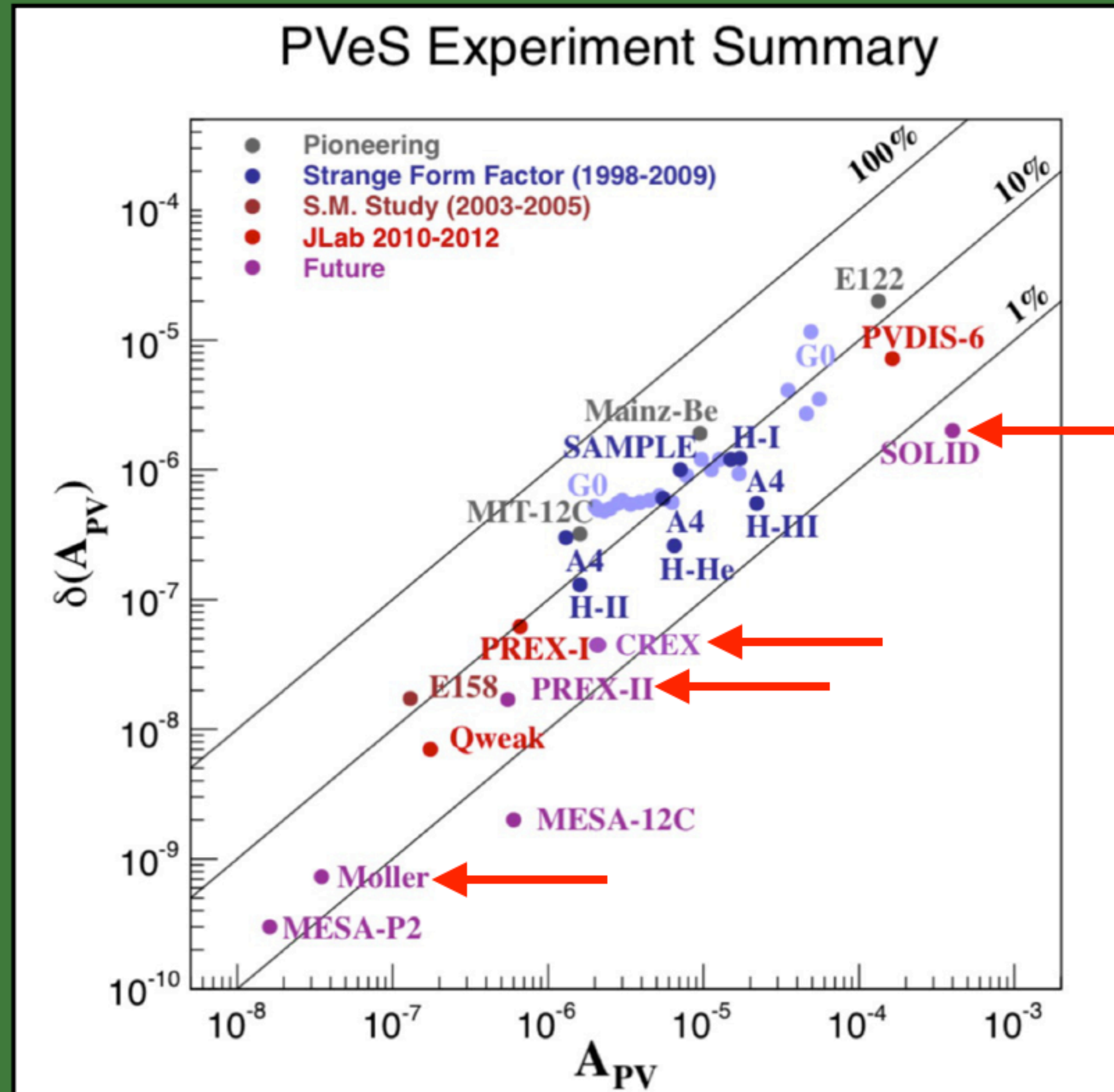
Average analyzing power from **Simulation**

PRECISION MØLLER POLARIMETRY

Parity-Violating Electron Scattering Experiments

Motivation for PVeS

- Measure the weak charge form factors
- Search for Physics Beyond the Standard Model
- Neutron radii for heavy nuclei
- Strange quark content of nucleon



PRECISION MØLLER POLARIMETRY

Table taken from talk by K. Paschke

Achieved

PREX-I
E=1.1 GeV, 5°
A=0.6 ppm

Charge Normalization	0.2%
Beam Asymmetries	1.1%
Detector Non-linearity	1.2%
Transverse Asym	0.2%
Polarization	1.3%
Target Backing	0.4%
Inelastic Contribution	<0.1%
Effective Q^2	0.5%
Total Systematic	**2.1%**
Total Statistical	**9%**

PREX-II
E=1.1 GeV, 5°
A=0.6 ppm

Charge Normalization	0.1%
Beam Asymmetries*	1.1%
Detector Non-linearity*	1.0%
Transverse Asym	0.2%
Polarization*	1.1%
Target Backing	0.4%
Inelastic Contribution	<0.1%
Effective Q^2	0.4%
Total Systematic	**2%**
Total Statistical	**3%**

CREX
E=2.2 GeV, 4°
A = 2 ppm

Charge Normalization	0.1%
Beam Asymmetries	0.3%
Detector Non-linearity	0.3%
Transverse Asym	0.1%
Polarization	0.8%
Target Contamination	0.2%
Inelastic Contribution	0.2%
Effective Q^2	0.8%
Total Systematic	**1.2%**
Total Statistical	**2%**

Systematic Errors Are Dominated by Polarimetry!

PRECISION MØLLER POLARIMETRY

Past Precision Experiments

Experiment	Beam energy	Polarization	Polarimetry precision
JLab GEp/GMp (1999)[5]	1–4 GeV	60%	3%
SLAC E154 DIS $g1n$ (1997)[13]	48 GeV	82%	2.4%
HERMES $g1n$ DIS (2007)[14]	30 GeV	55%	2.9%
SLAC 122 PV-DIS (1978)[7]	16–22 GeV	37%	6%
Bates SAMPLE (2000)[15]	0.2 GeV	39%	4%
MAMI PV-A4 (2004)[16]	0.85 GeV	80%	2.1%
JLab Qweak (2017)[11]	1.2 GeV	88%	0.62%
SLD A_{LR} (2000)[17]	46.5 GeV	75%	0.5%

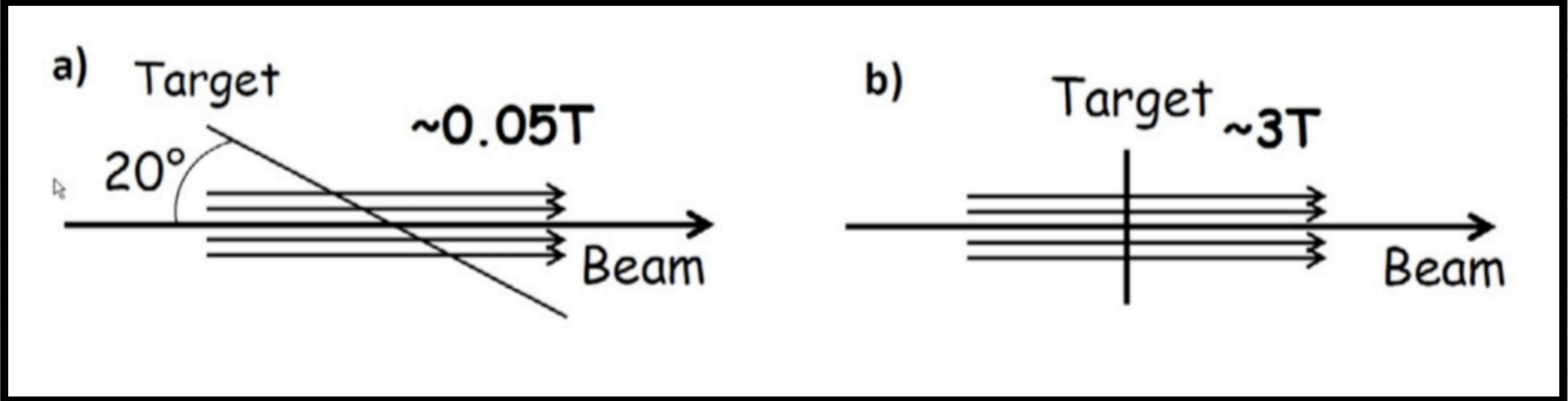
Aulenbacher, Kurt, et al. "Precision electron beam polarimetry for next generation nuclear physics experiments." International Journal of Modern Physics E 27.07 (2018): 1830004.

Future Precision Experiments in Hall A

PREX II (June 2019)	**0.95GeV**	**~85%**	**1.1%**
CREX (November 2019)	**2.20GeV**	**~85%**	**0.8%**
MOLLER (202x?)	**11.0GeV**	**~85%**	**0.42%**

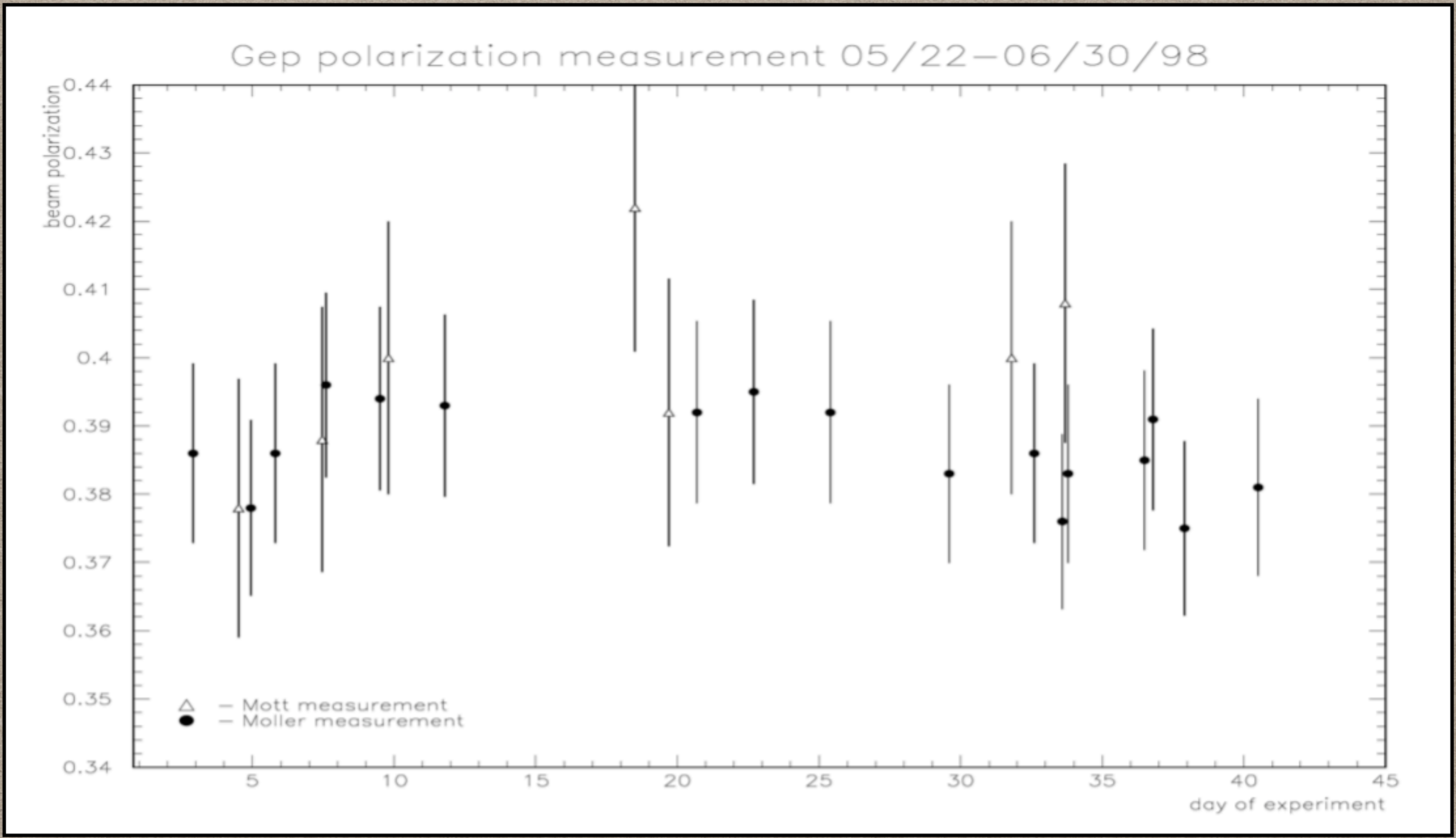
Systematic Errors

	Tilted Target 1998-2005	Tilted Target 2005-2015	Brute Force Method 2010
Target polarization	3.5%	2.0%	0.5%
Target angle	0.5%	0.5%	0.0%
Analyzing power	0.3%	0.3%	0.3%
Levchuk effect	0.2%	0.2%	0.2%
Dead time	0.3%	0.3%	0.3%
Others	-	-	0.3%
Total	3.6%	2.1%	$\sim$1.0%

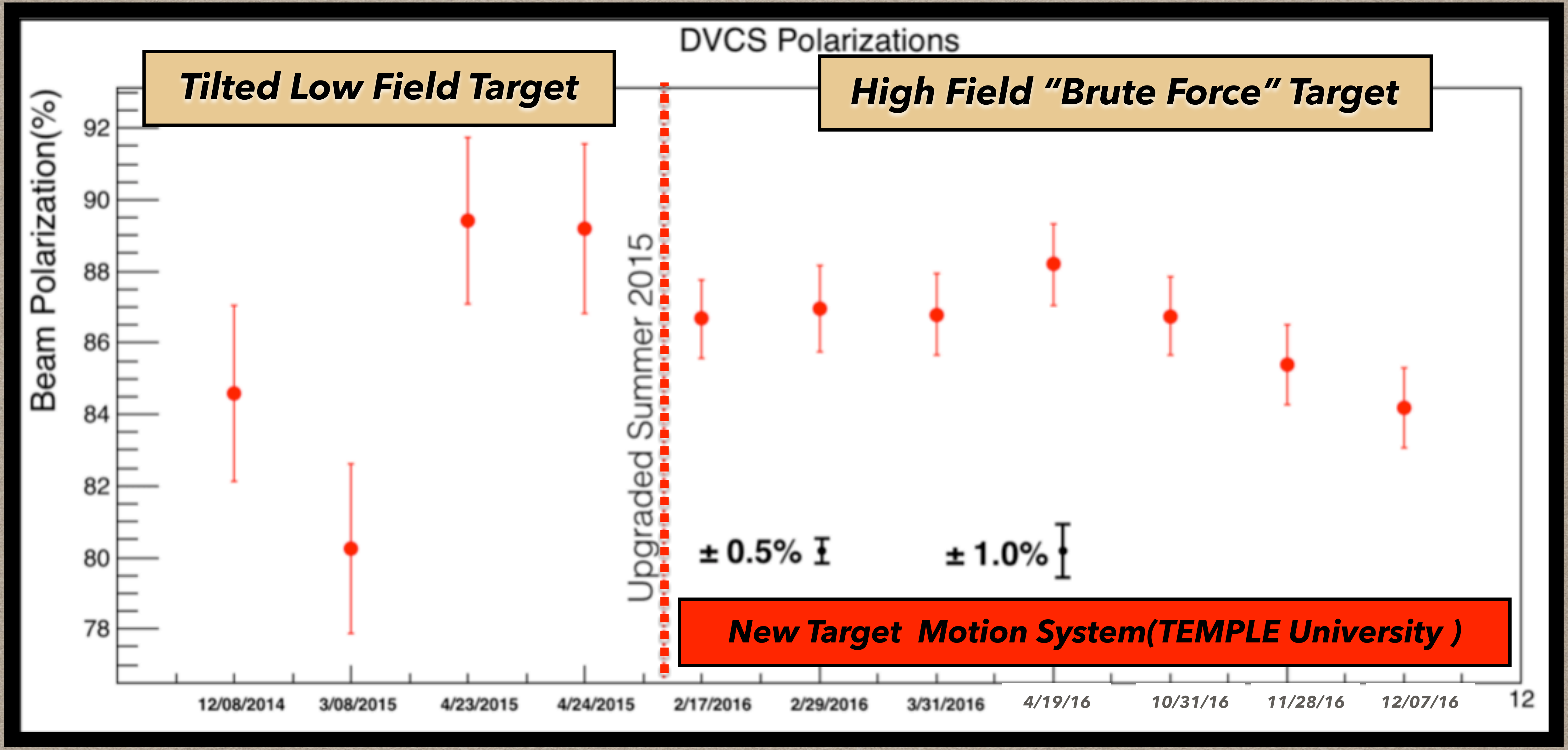


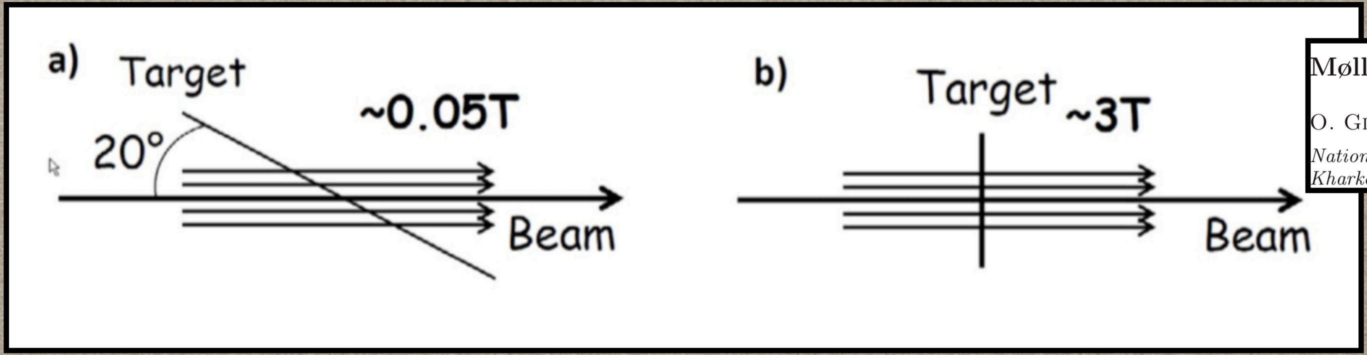
PRECISION MØLLER POLARIMETRY

1998: Systematic Error was at 3%



POLARIMETRY MEASUREMENTS (DVCS)





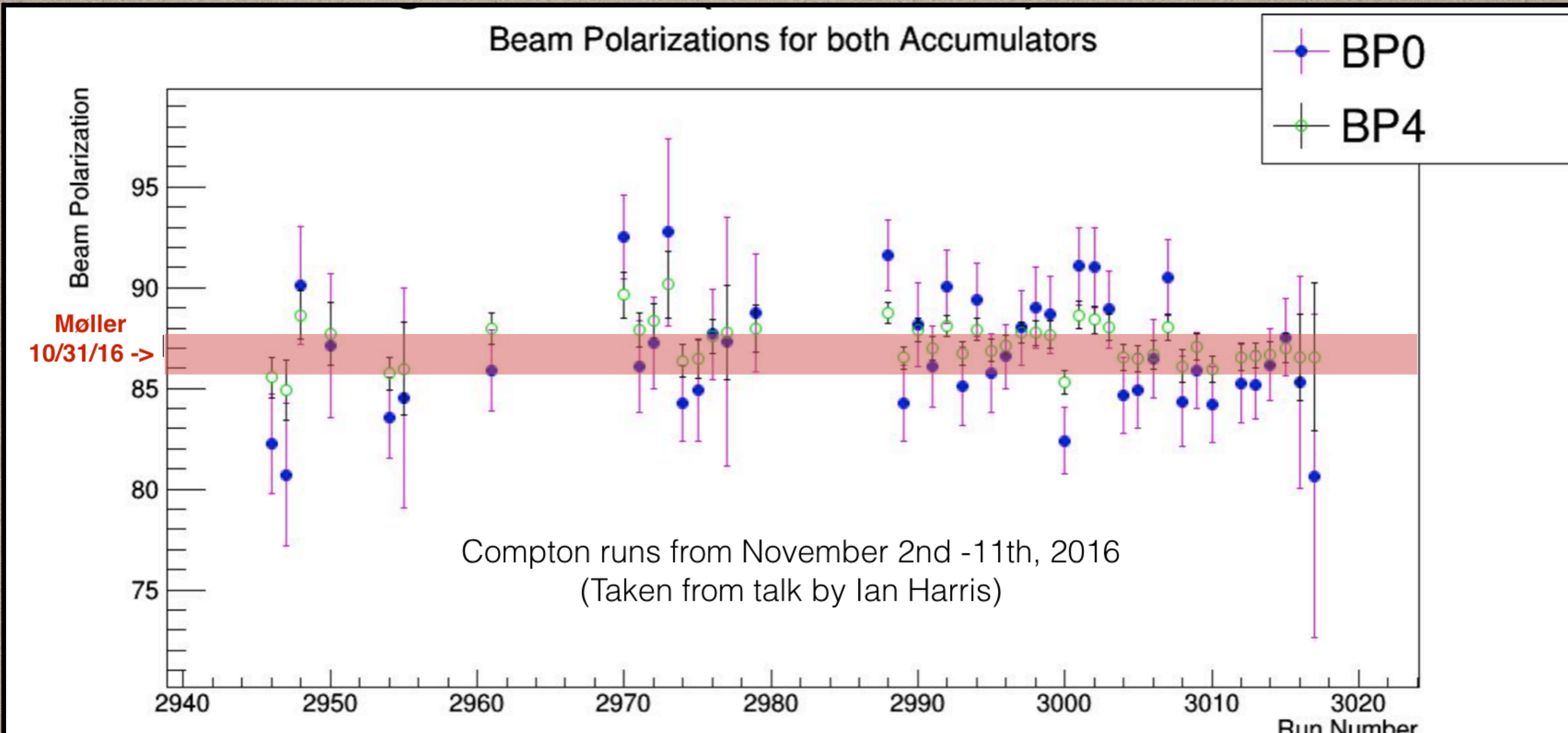
Møller (iron foils) existing techniques

O. Glamazdin

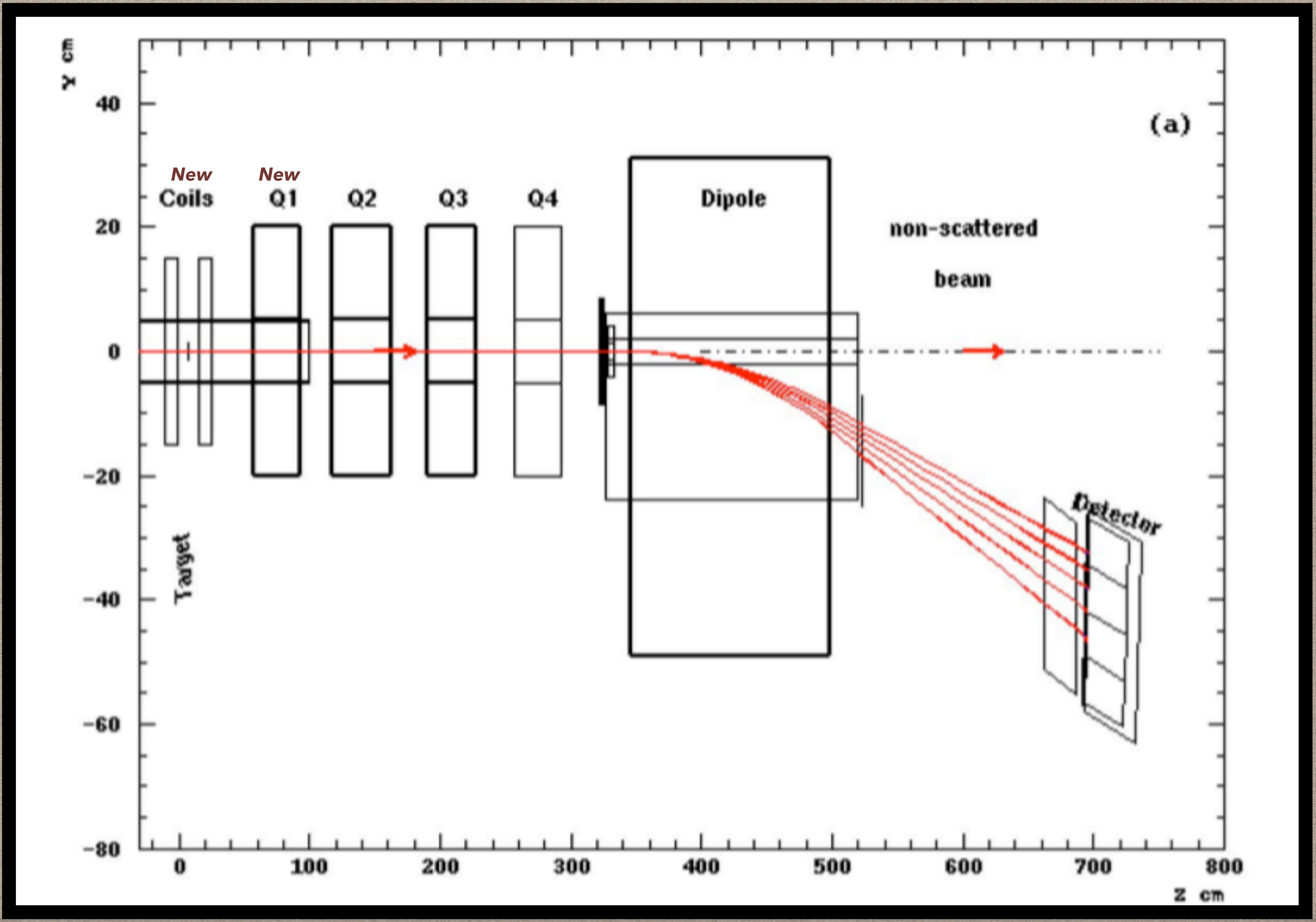
National Science Center Kharkov Institute of Physics and Technology
Kharkov 61108, Ukraine

POLARIMETRY MEASUREMENTS (DVCS)

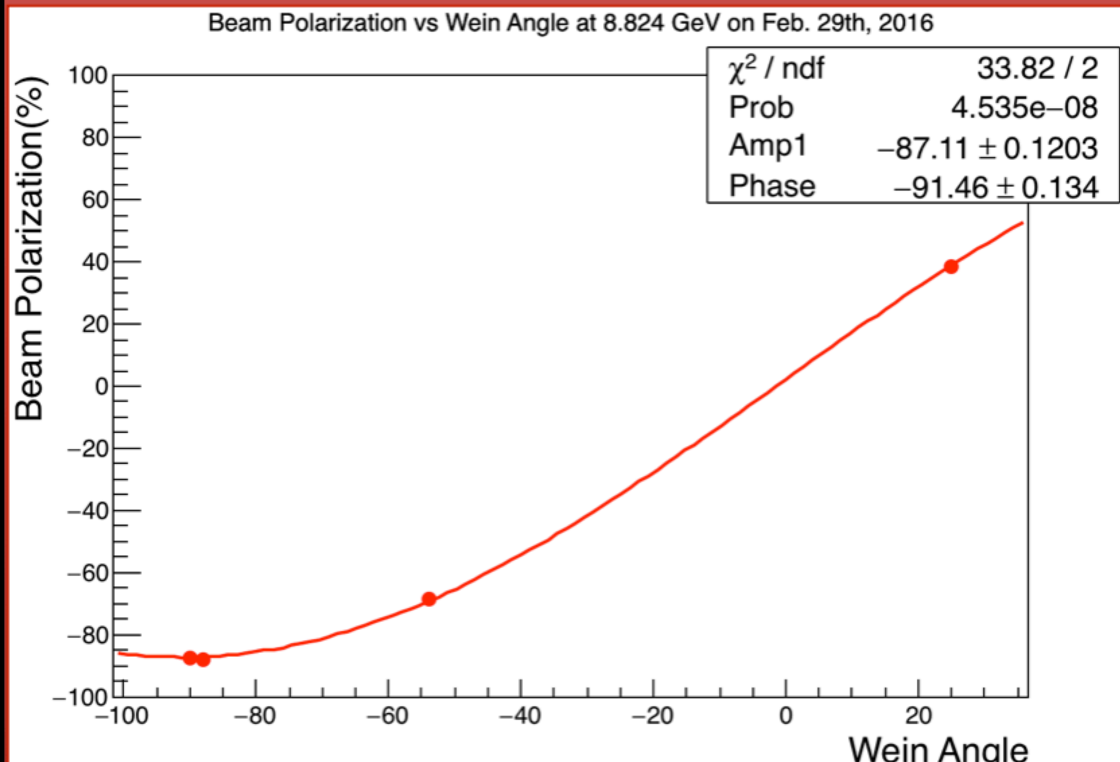
Comparison with Compton Polarimeter

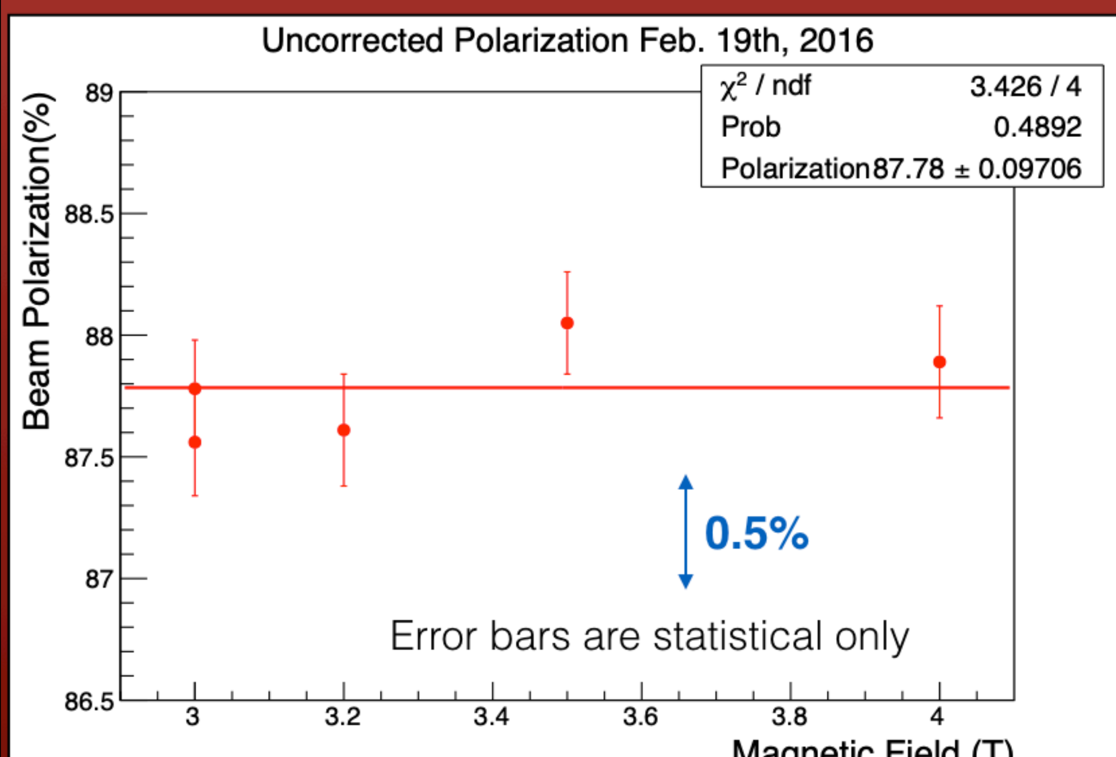


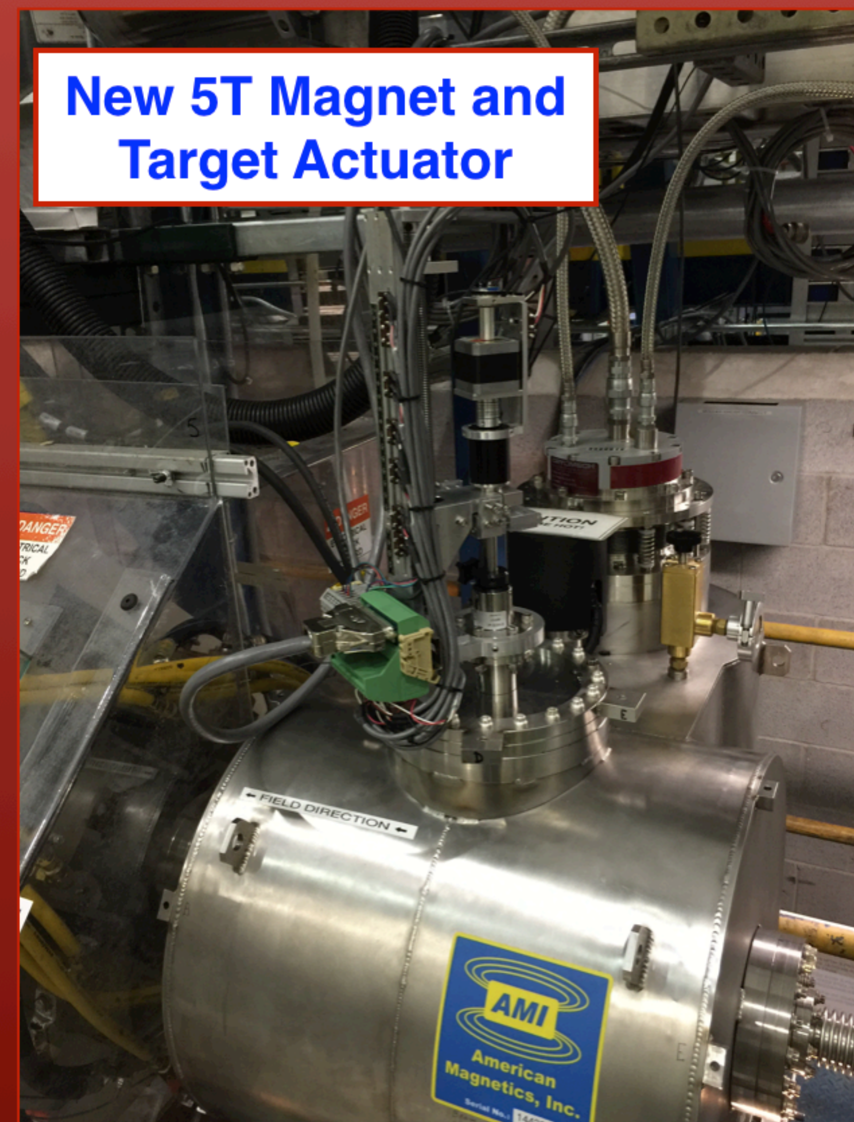
EXPERIMENTAL SET-UP

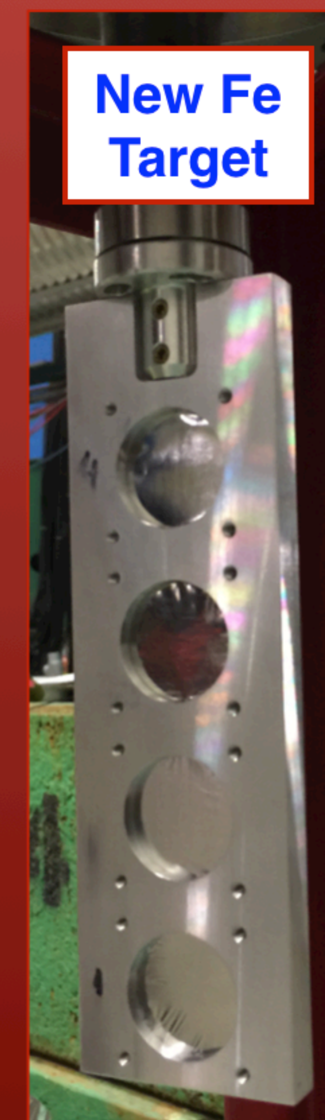


EXPERIMENTAL SET-UP (2016)

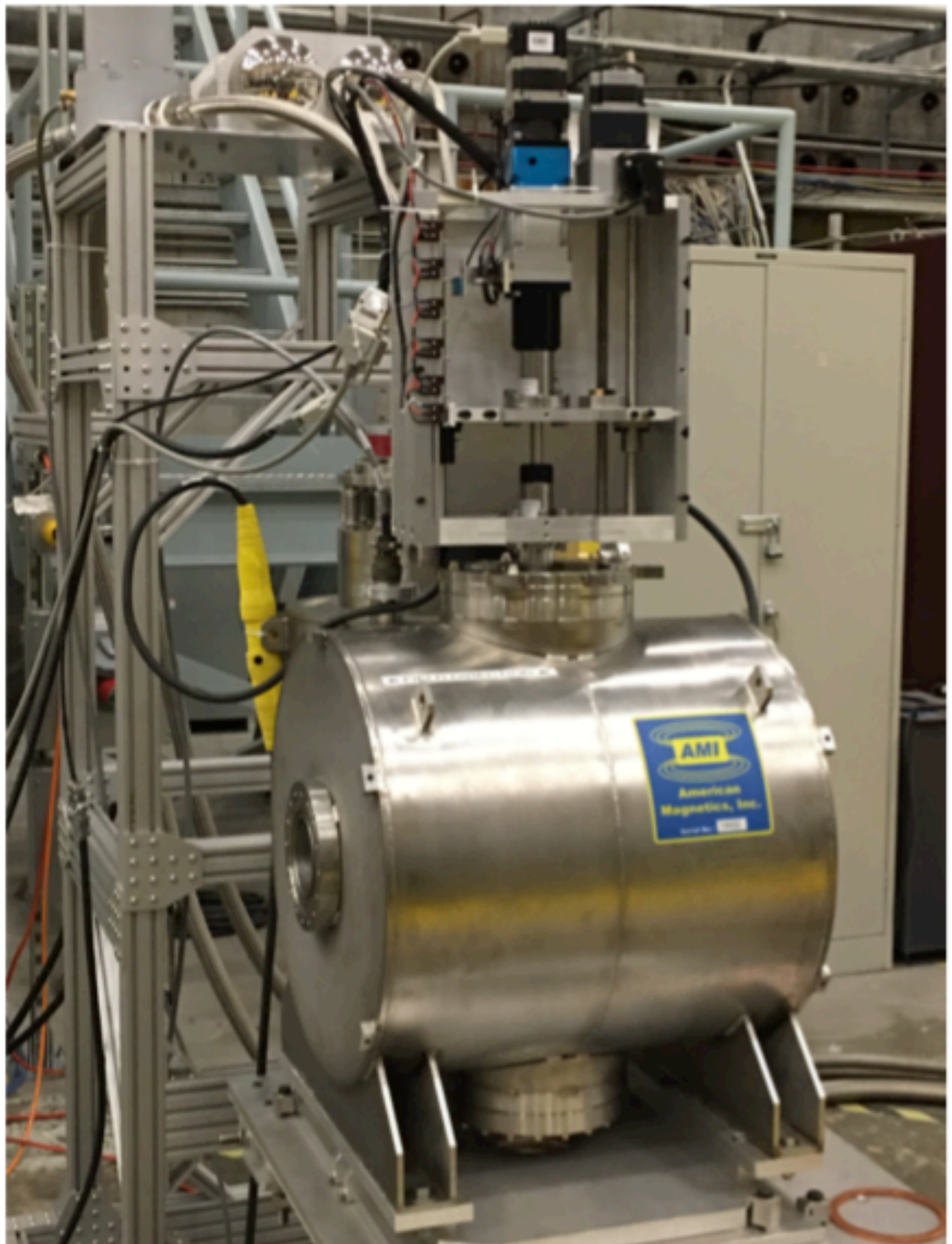


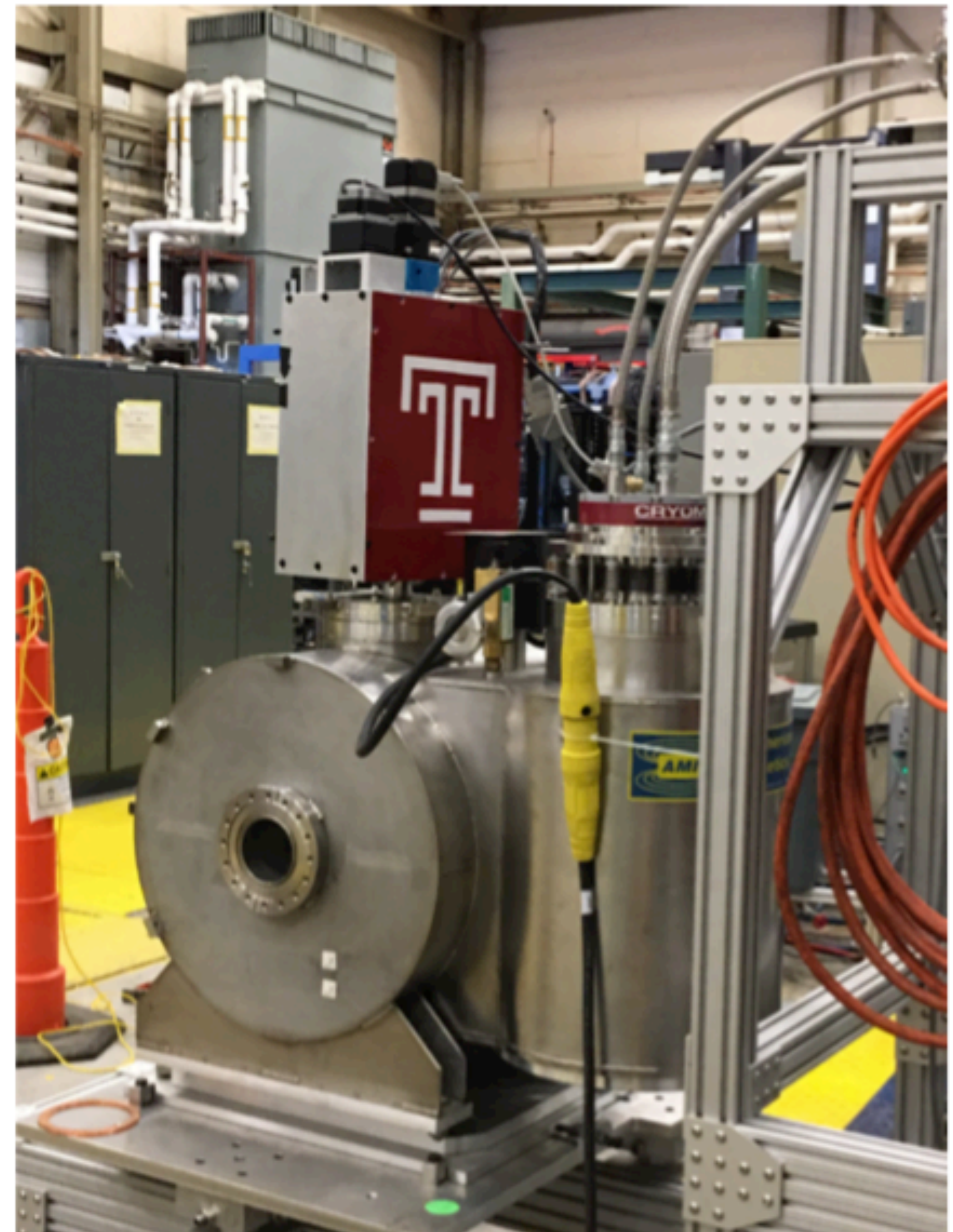




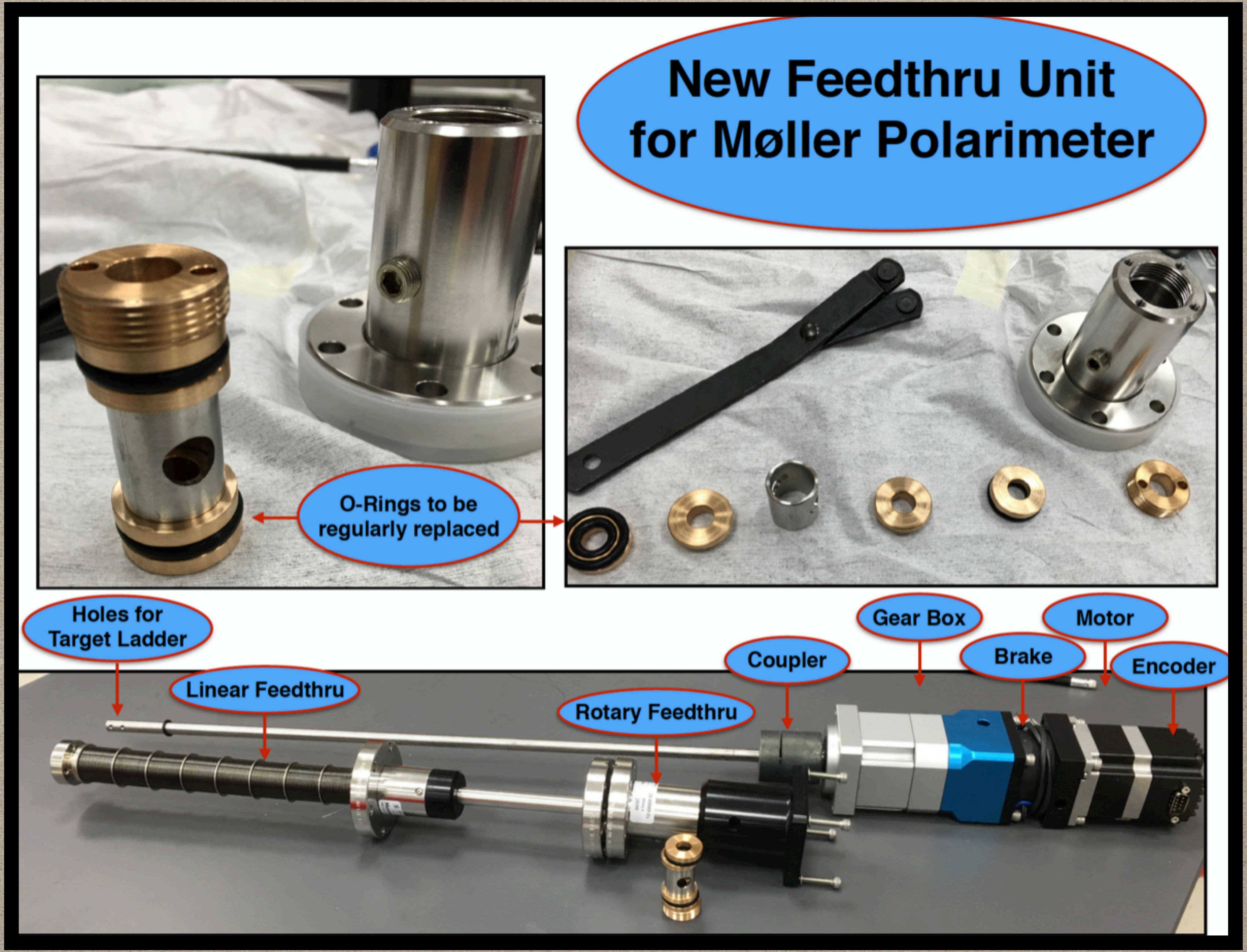


EXPERIMENTAL SET-UP (2019)





EXPERIMENTAL SET-UP (2019)



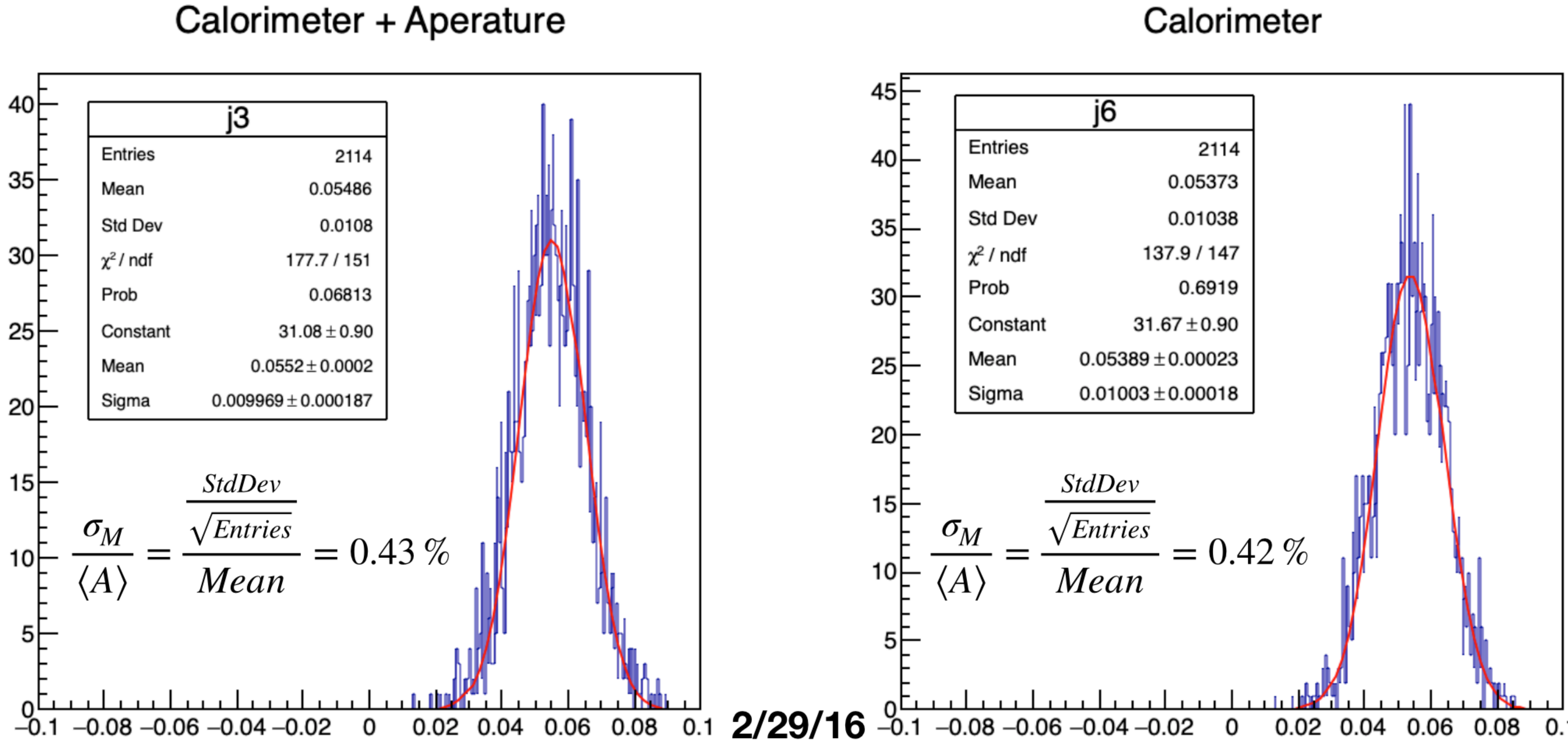
ERRORS: BUDGET FOR MOLLER

Table 4.1: Error budget for MOLLER experiment

Systematic Effect	Proposed Error	Strategic Approach
Target Polarization	0.25%	Demonstrate saturation vs **B** and tilt angle
Analyzing Power	0.20%	Accurate spectrometer simulation
Levchuk Effect	0.20%	Simulation with atomic modeling
Target Heating	0.05%	Match data to heating calculation
Deadtime	0.10%	Confirm "zero dead time" w/ FADC
Background	0.10%	Measurements with beam
Others	0.10%	*see text*
Total	0.42%	

Taken From MOLLER MIE

ERRORS: STATISTICAL



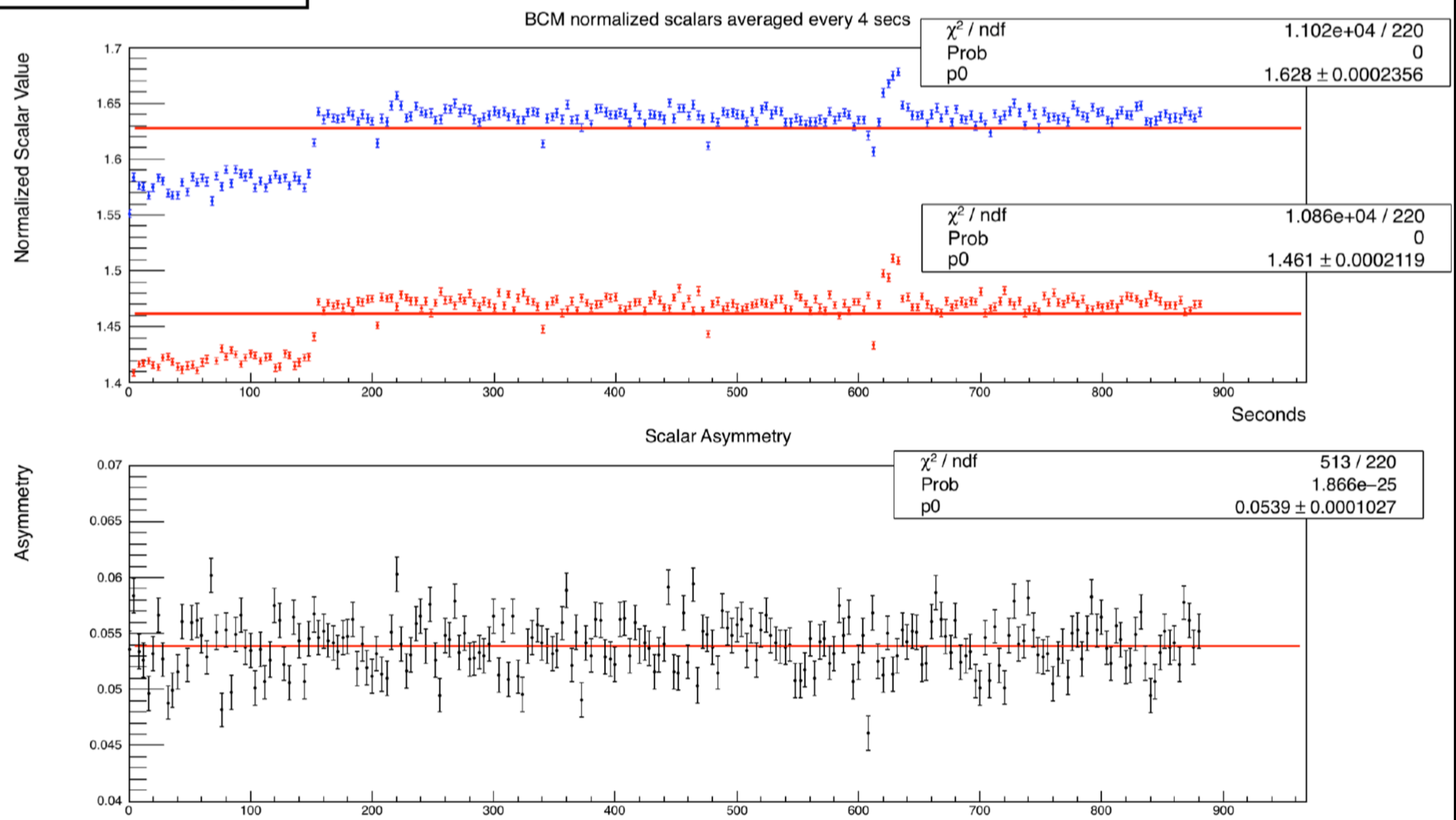
2/29/16
8.8 GeV
Target 3 (12.5µm)
0.7 µA
4min 53 sec
59kHz

ERRORS: STATISTICAL

Data Analysis

- March 31st 2016,
- E_{Beam}=11GeV
- 1μA
- 12.5μm Fe Target

Rate=53k Hz



Statistical Precision of 0.19% for a ~15 minute of data taking (6 runs)

ERRORS: STATISTICAL

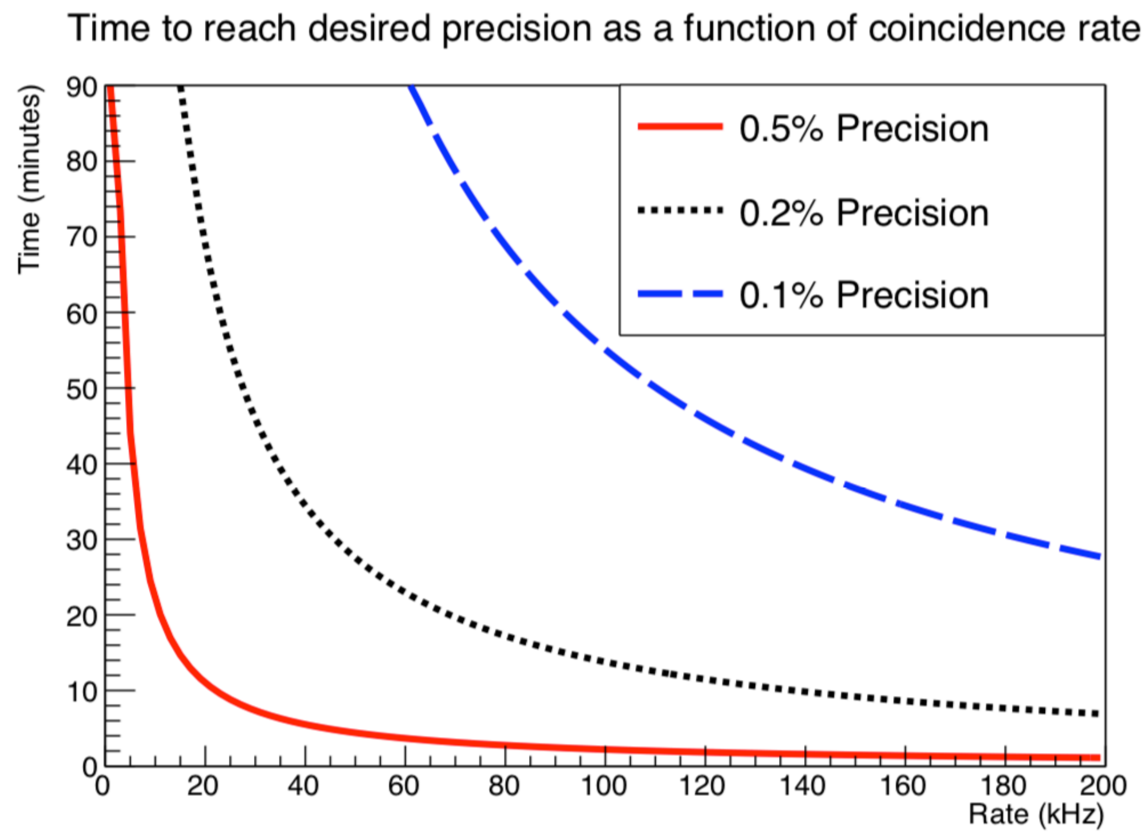


Figure 4.6: Time vs. rate

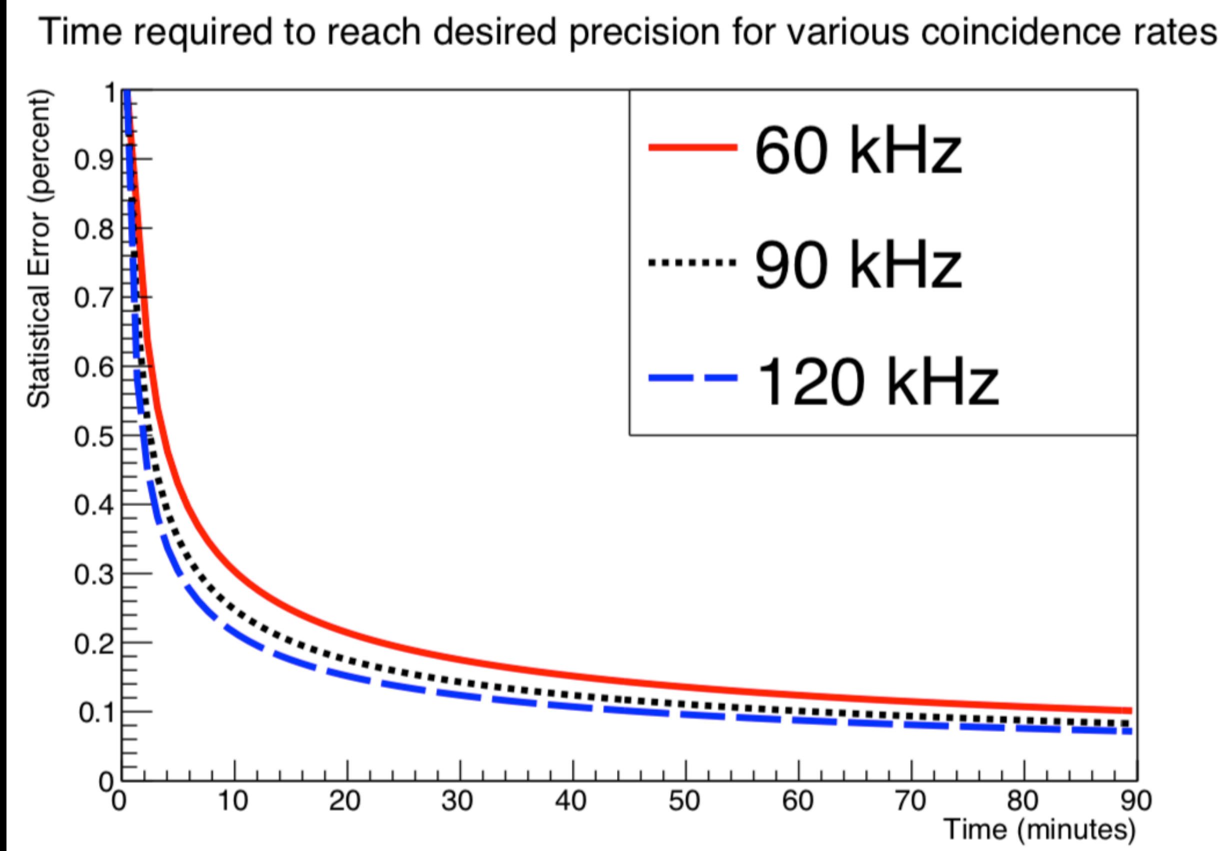


Figure 4.7: Statistical Error vs. time

ERRORS: TARGET POLARIZATION

A target for precise Møller polarimetry

L.V. de Bever*, J. Jourdan, M. Loppacher, S. Robinson, I. Sick, J. Zhao

Dept. für Physik und Astronomie, Universität Basel, CH-4056 Basel, Switzerland

Received 29 January 1997

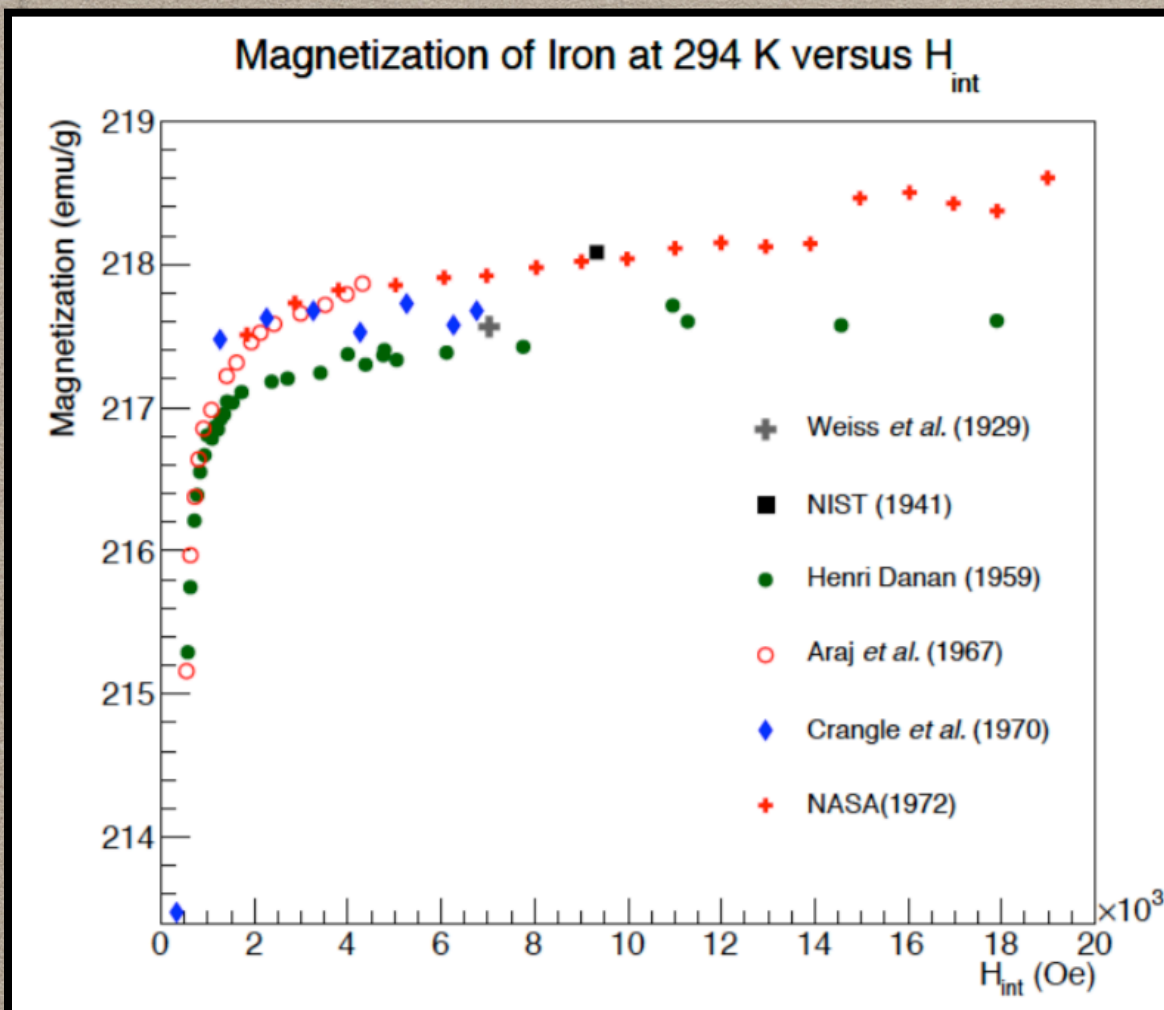
Effect	M_s [μ_B]	Error
Saturation magnetization ($T \to 0$ K, $B \to 0$ T)	2.2160	±0.0008
Saturation magnetization ($T = 294$ K, $B = 1$ T)	2.177	±0.002
Corrections for $B = 1$–4 T	0.0059	±0.0002
Total magnetization	2.183	±0.002
Magnetization from orbital motion	0.0918	±0.0033
Remaining magnetization from spin	2.0911	±0.004
Target electron polarization ($T = 294$ K, $B = 4$ T)	0.08043	±0.00015

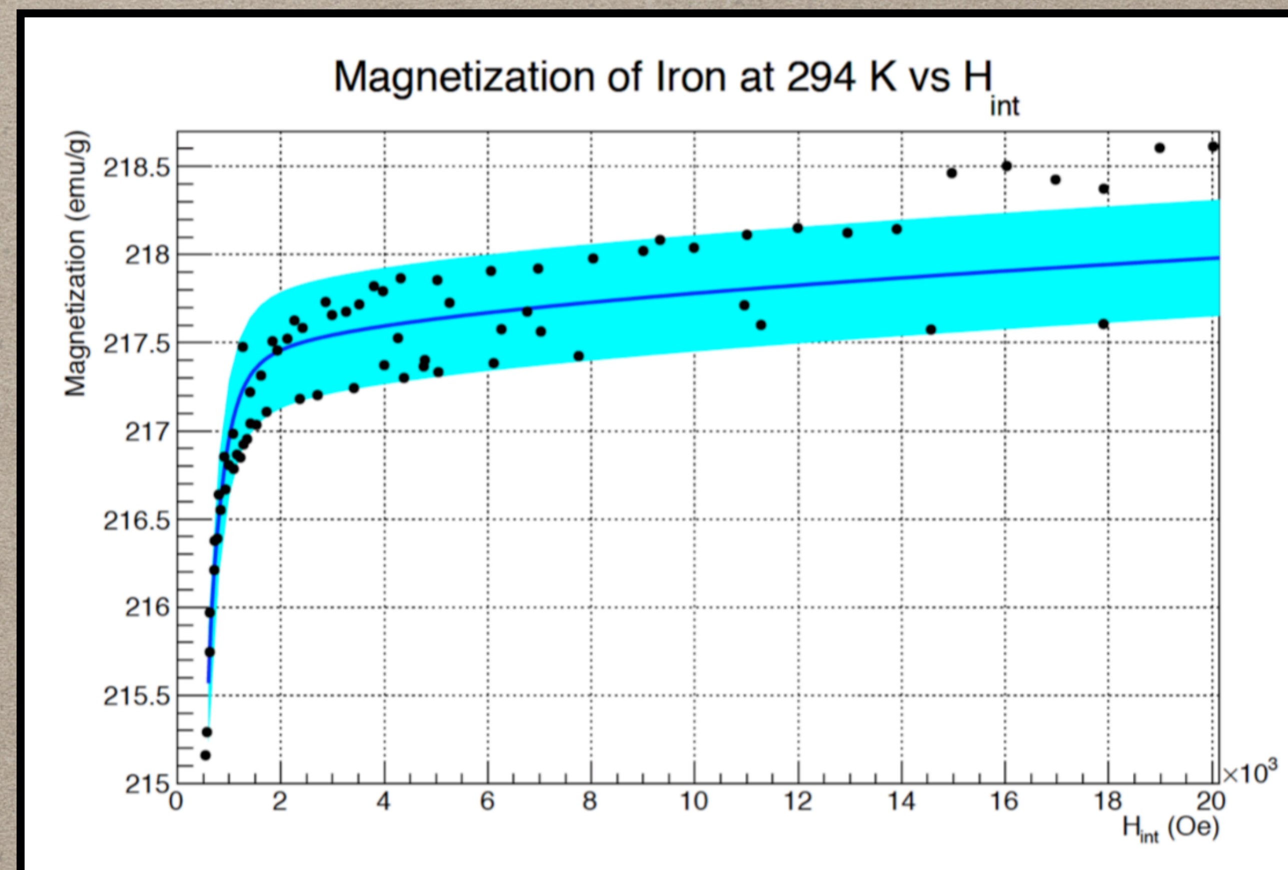
ERRORS: TARGET POLARIZATION

Target Foil Polarization for Møller Polarimetry in Hall A

Donald Jones
Temple University

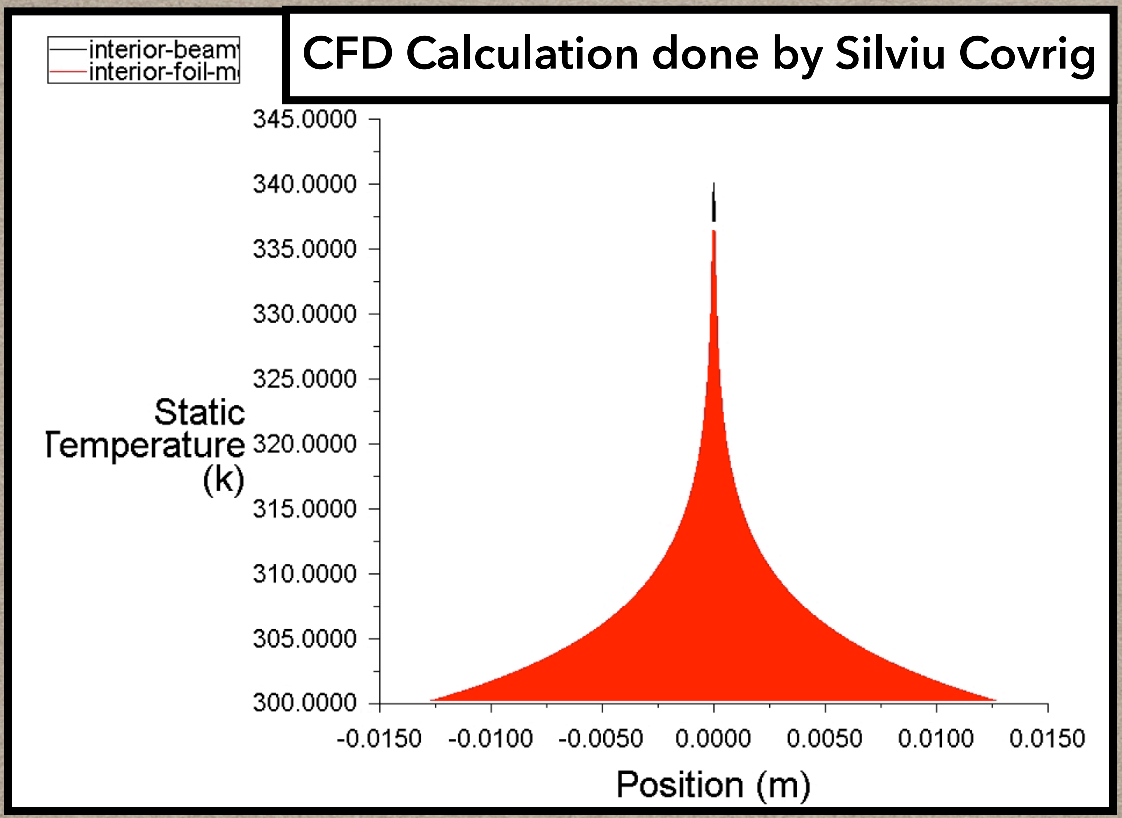
September 20, 2017

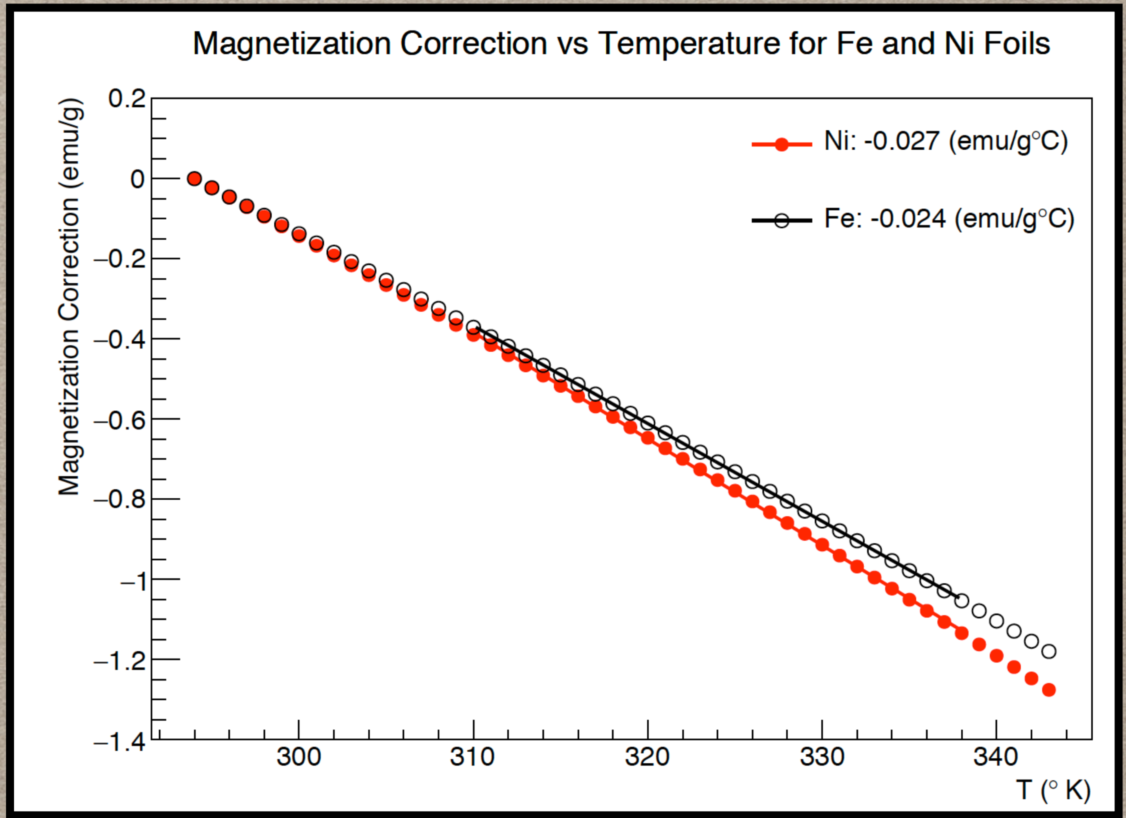




ERRORS: TARGET POLARIZATION

TARGET HEATING





Recommendation: assume average temperature is about 1-2 degrees less than the maximum temperature differential and that uncertainty is about 15%

$\Delta T = 19 \pm 3(°C/\mu A)$ for both nickel and iron

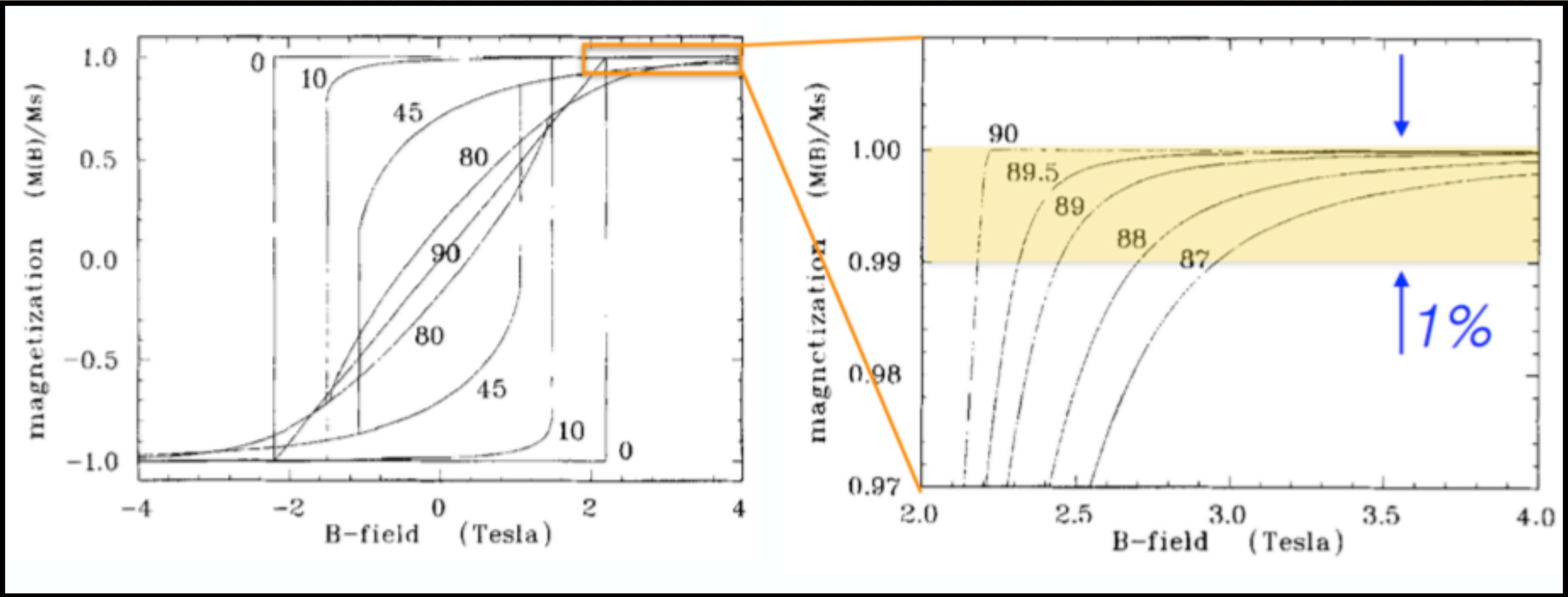
ERRORS: TARGET POLARIZATION

Conclusions from Don's Study

The error in target polarization listed in the MEI proposal for the MOLLER experiment was 0.25%. This study concludes that the polarization at room temperature of a saturated Fe foil can be known to 0.28% and that of an Ni foil to 0.45%. Additional uncertainty associated with the temperature correction under a 1 μA electron beam load takes the relative uncertainties for Fe and Ni to 0.3% and 0.48%. However, the combination of measurements on Ni and Fe foils will reach the 0.25% level even under a 1 μA beam load.

ERRORS: TARGET POLARIZATION

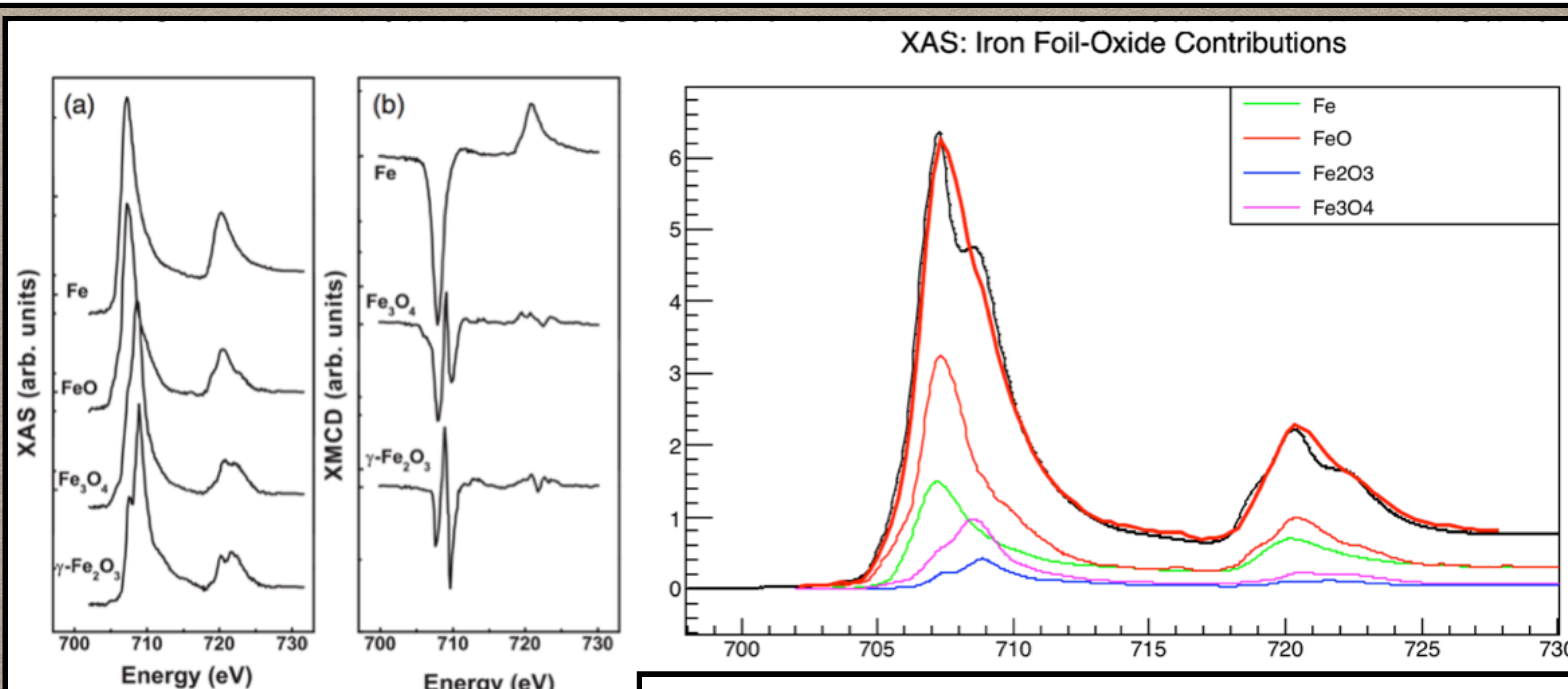
Target Angle needs to be well known to limit uncertainity on target magnetization!



ERRORS: TARGET POLARIZATION

X-RAY MAGNETIC CIRCULAR DICHROISM (XMCD) SPECTROSCOPY OF IRON FOILS

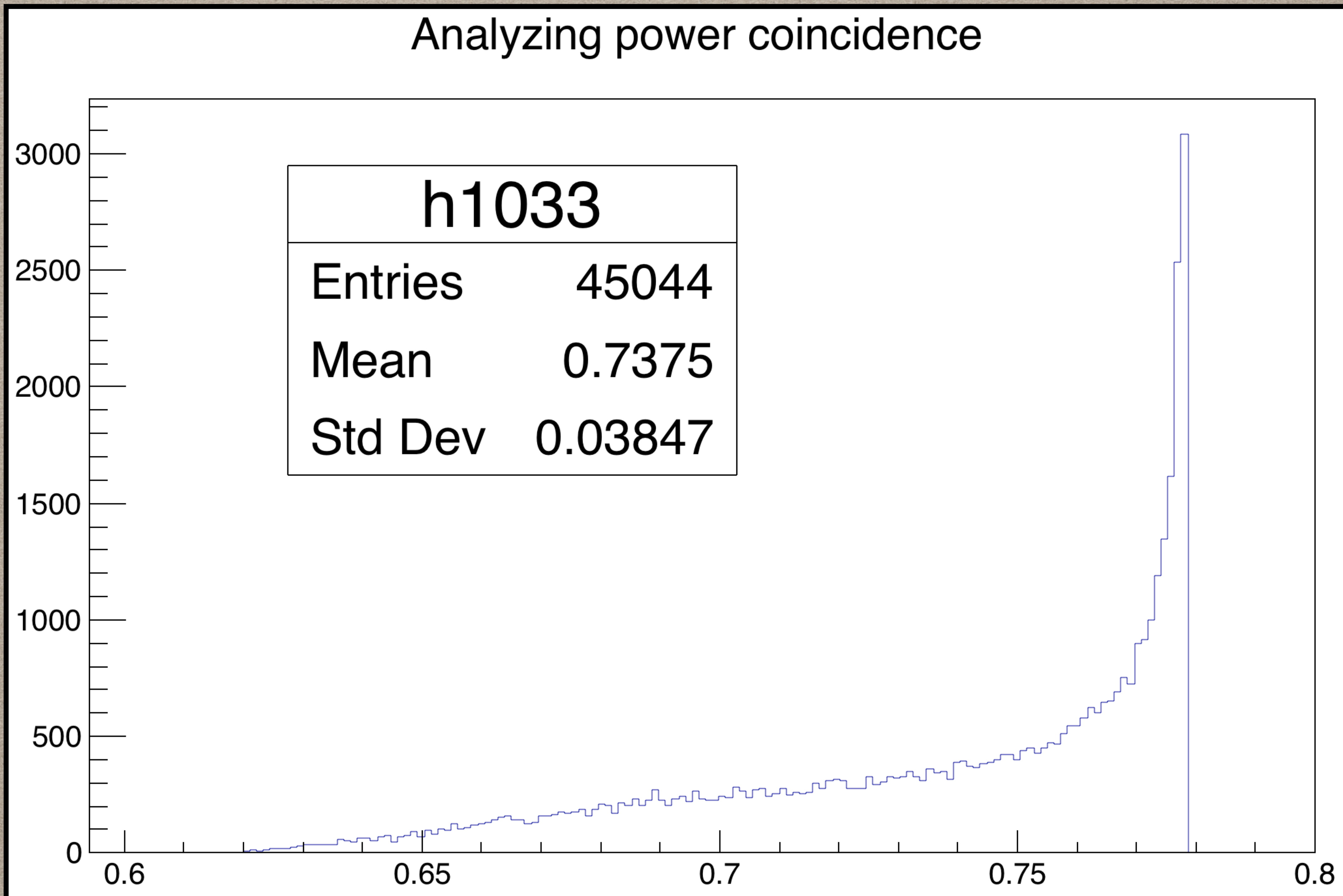
Possibility of future XMCD analysis being discussed at Temple which could be a new method to confirm target magnetization and/or g'



Oxidation Seen On Foil Surface

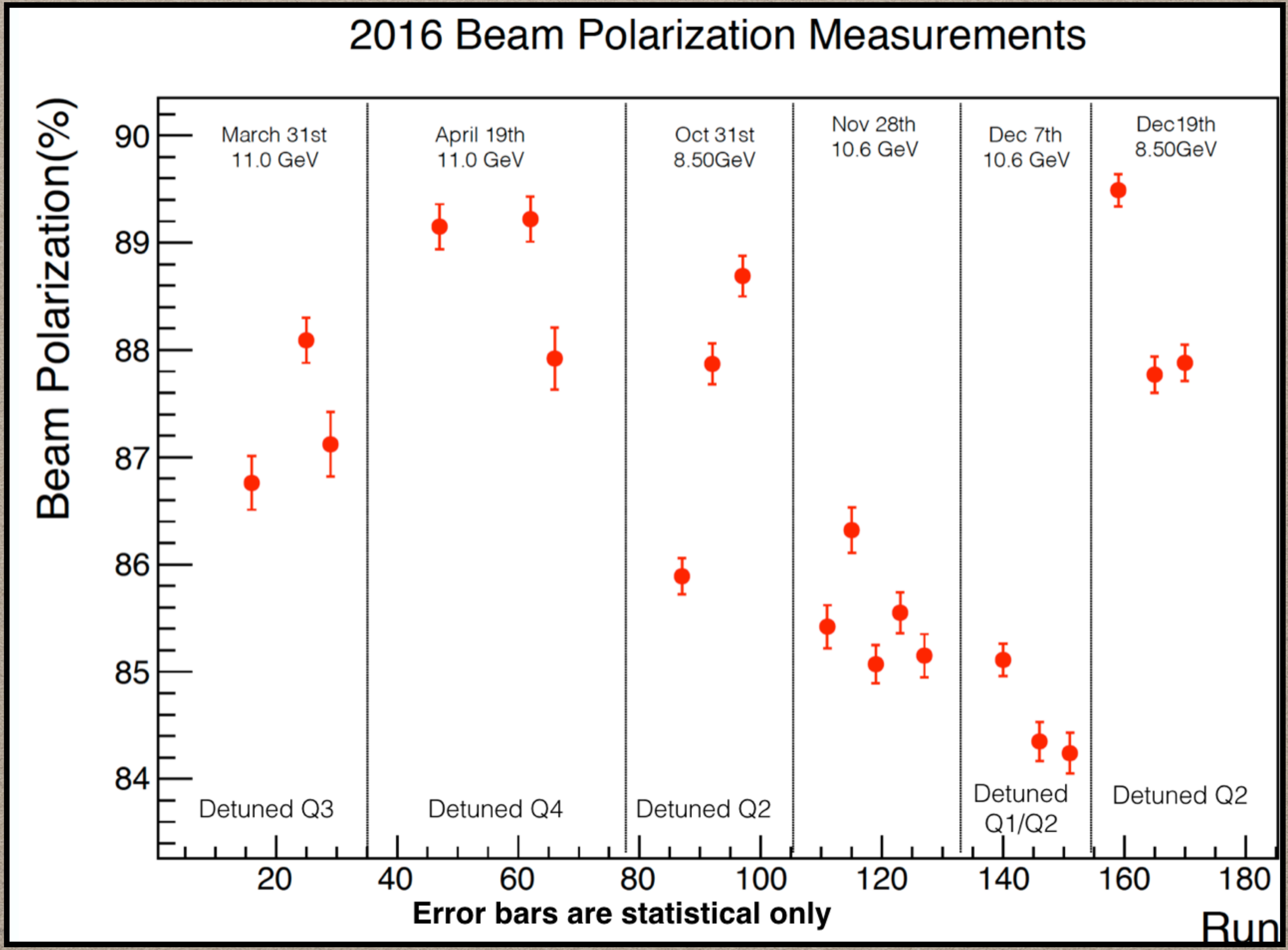
ERRORS: ANALYZING POWER

Detector Acceptance determines <Azz> which we infer from simulation

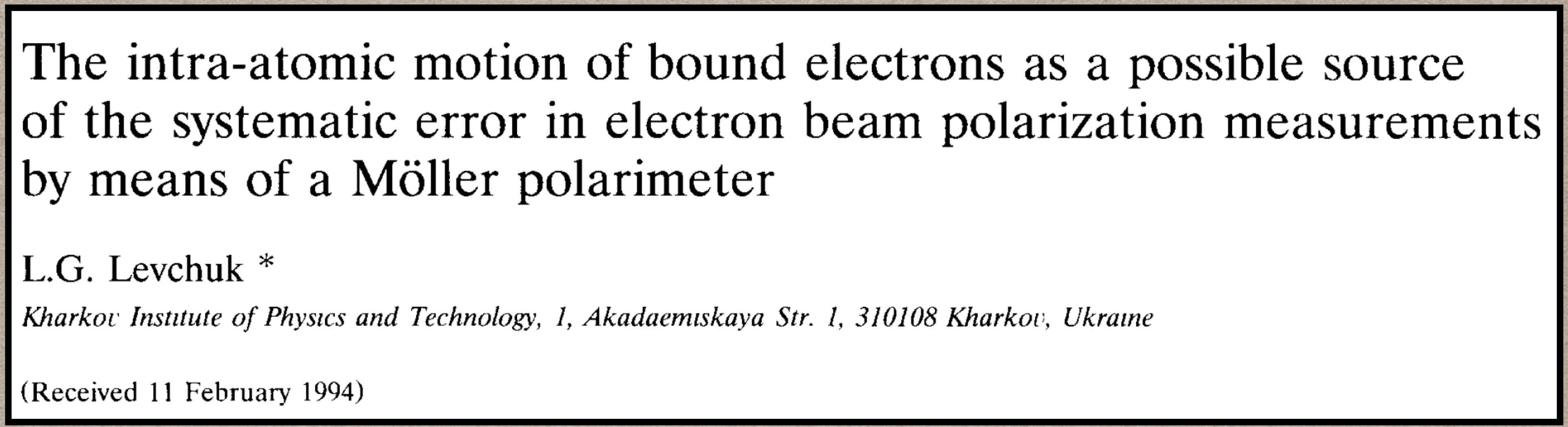


ERRORS: ANALYZING POWER

This is what happens when you don't treat <Azz> properly with simulation (Different Quad Settings -> Different Acceptance -> Different <Azz>)



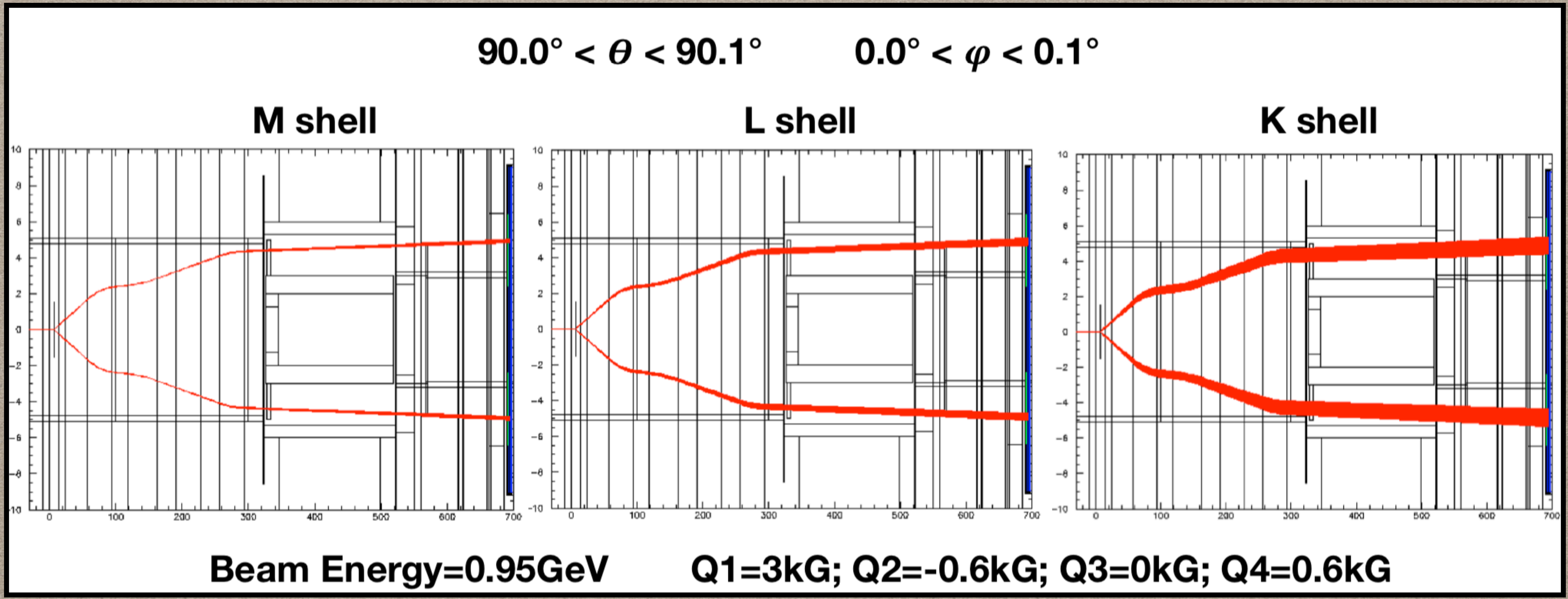
ERRORS: LEVCHUK EFFECT


The intra-atomic motion of bound electrons as a possible source of the systematic error in electron beam polarization measurements by means of a Möller polarimeter

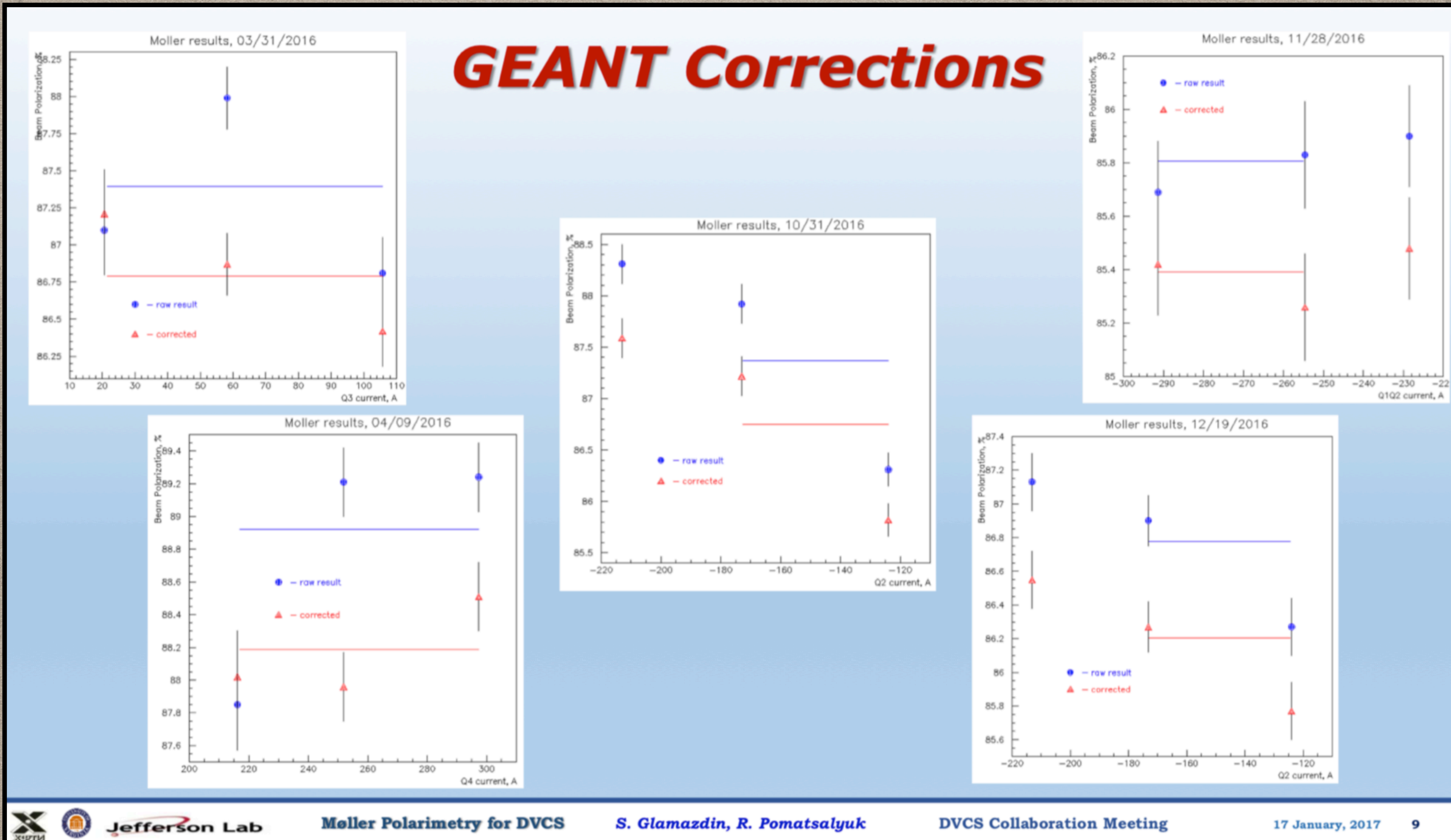
L.G. Levchuk *

Kharkov Institute of Physics and Technology, 1, Akadaemiskaya Str. 1, 310108 Kharkov, Ukraine

(Received 11 February 1994)



ERRORS: LEVCHUK EFFECT



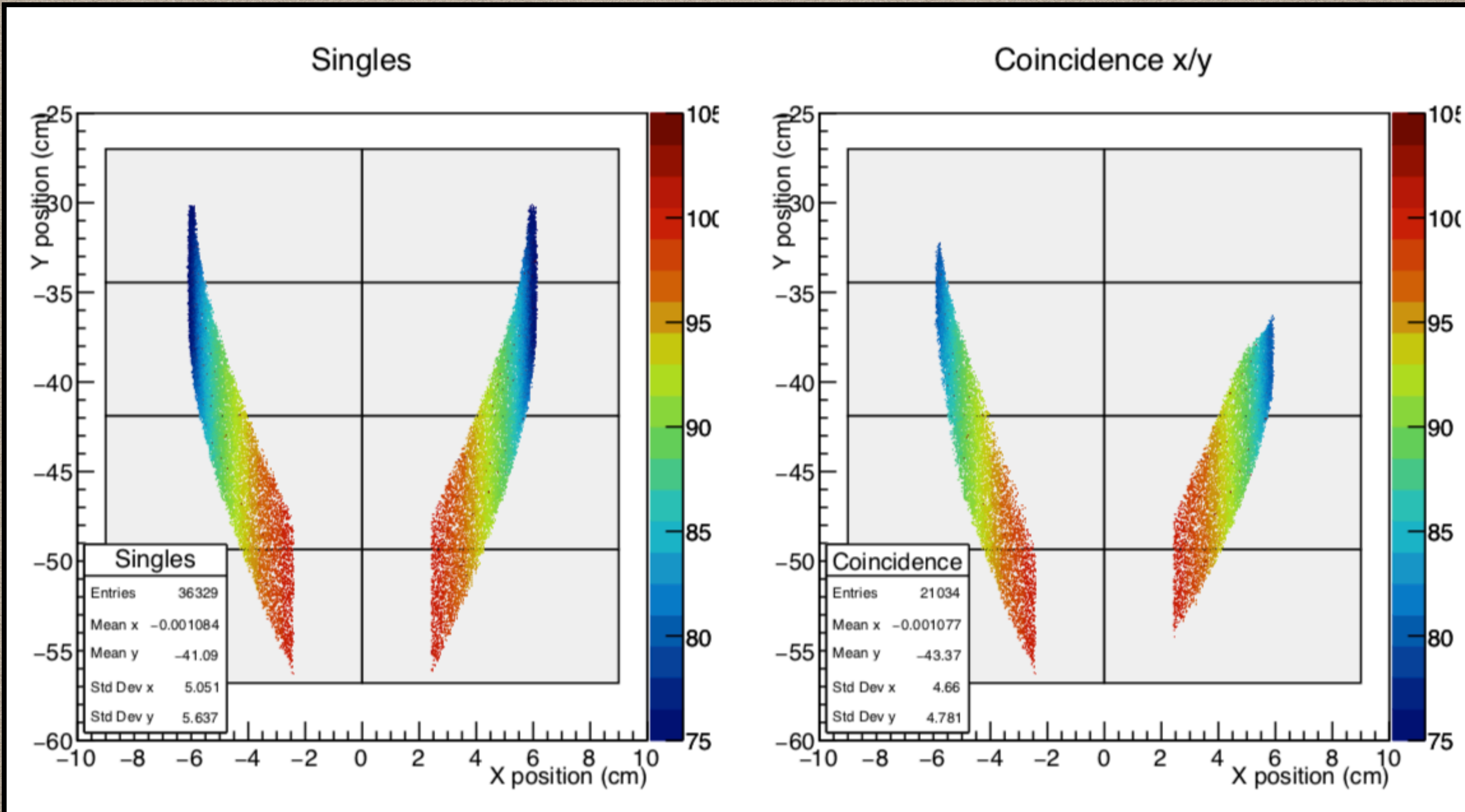
- **MONTE CARLO SIMULATION**
  - **NEW SCRIPTS**
  - **QUAD SCAN DATA COMPARISON**
  - **VALIDATION OF GEANT4**
  - **FIELD MAPPING OF TARGET MAGNET**

GEANT3 SIMULATION

- COMGeant- Interface to Geant3
- Precompiled executable (Difficult to modify)
- Limited expertise (Eugene Chudakov, Sasha Glamazdi)
- Analysis done with PAW and Fortran routines
- Multiple input files to define geometry and physics
- Needs to run on ifarm1101(CentOS 6.5)
- In use since 1998
- Currently being used to validate new Geant4 simulation
- How-to and documention coming soon
- Many new ROOT analysis scripts developed

GEANT3 SIMULATION: DETECTOR PLANE

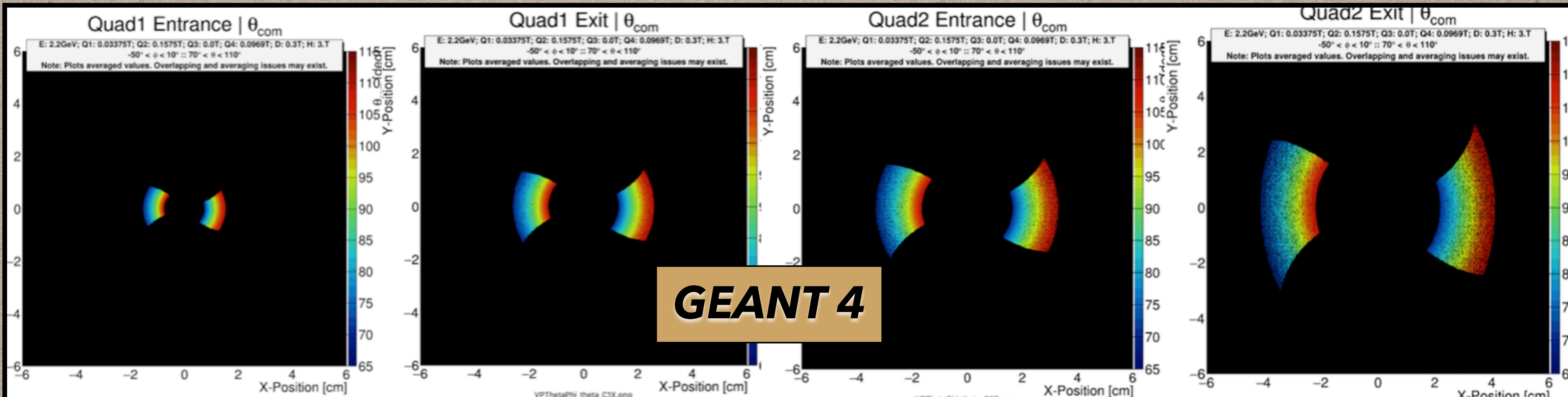
example ROOT analysis

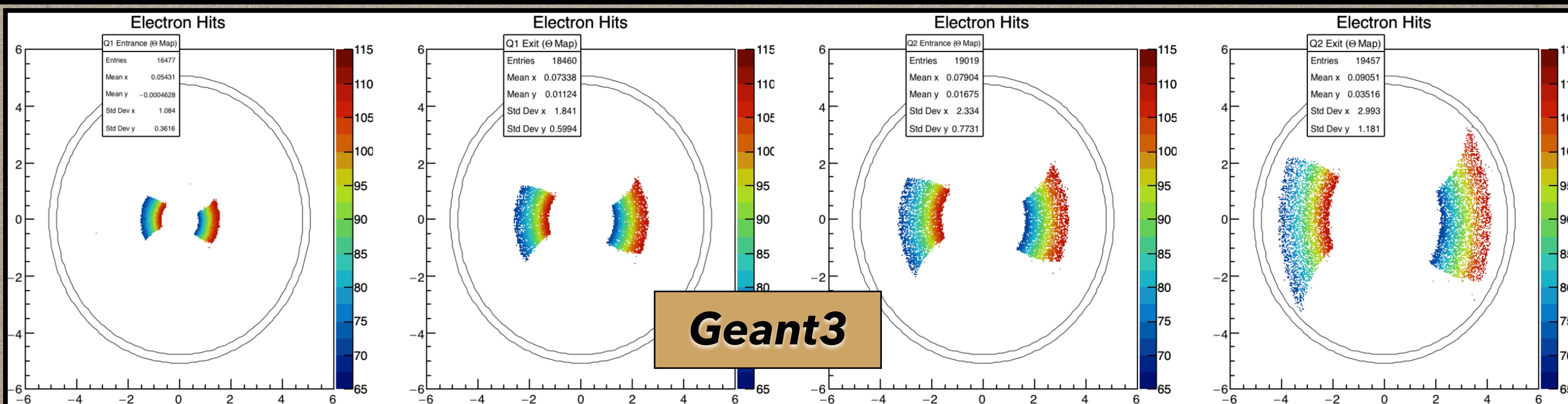


Holding field leads to L/R asymmetry

GEANT3 SIMULATION: VALIDATING GEANT4

Electrons at different planes in quadrupole region of beampipe

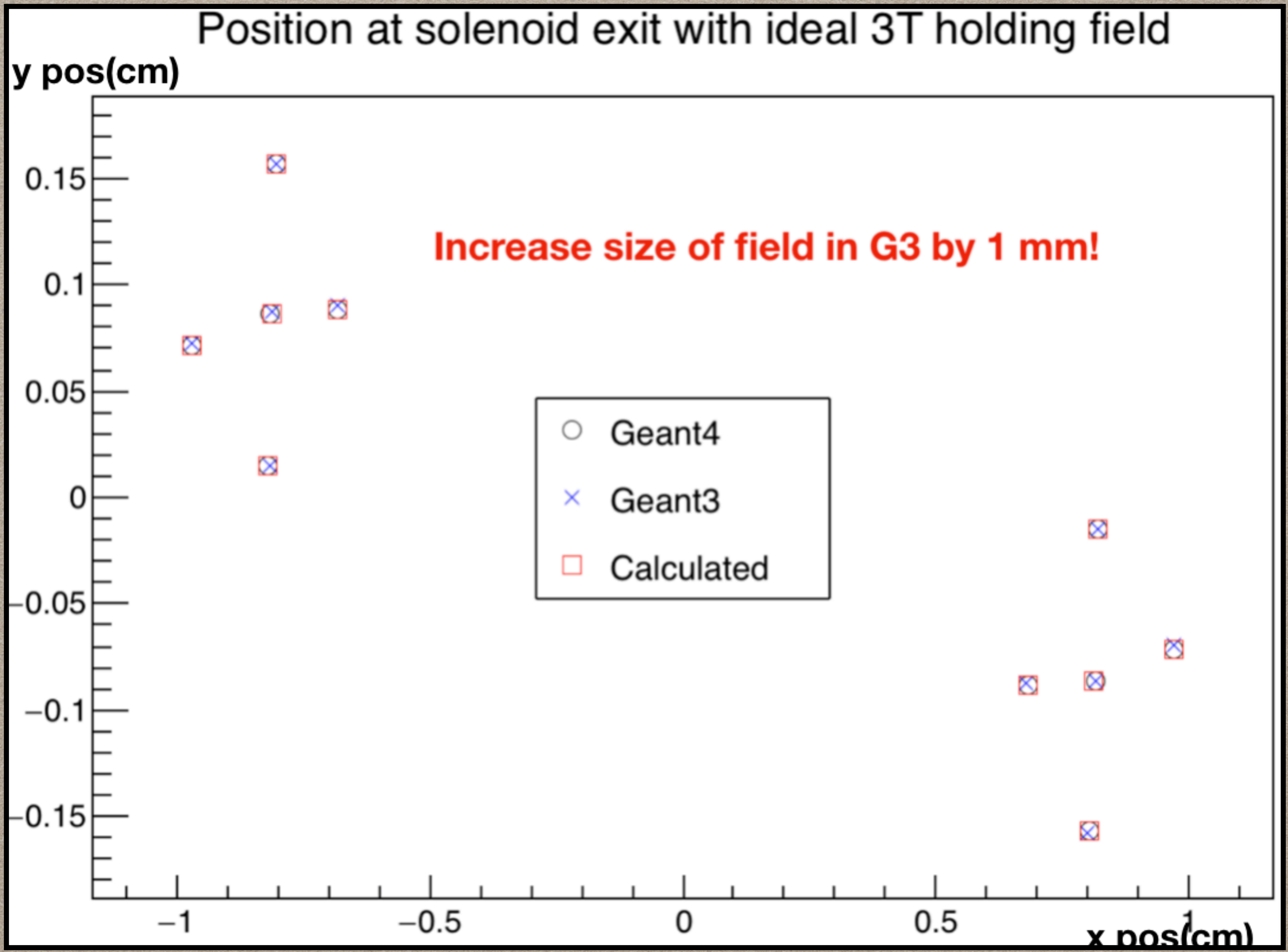




Increasing z position

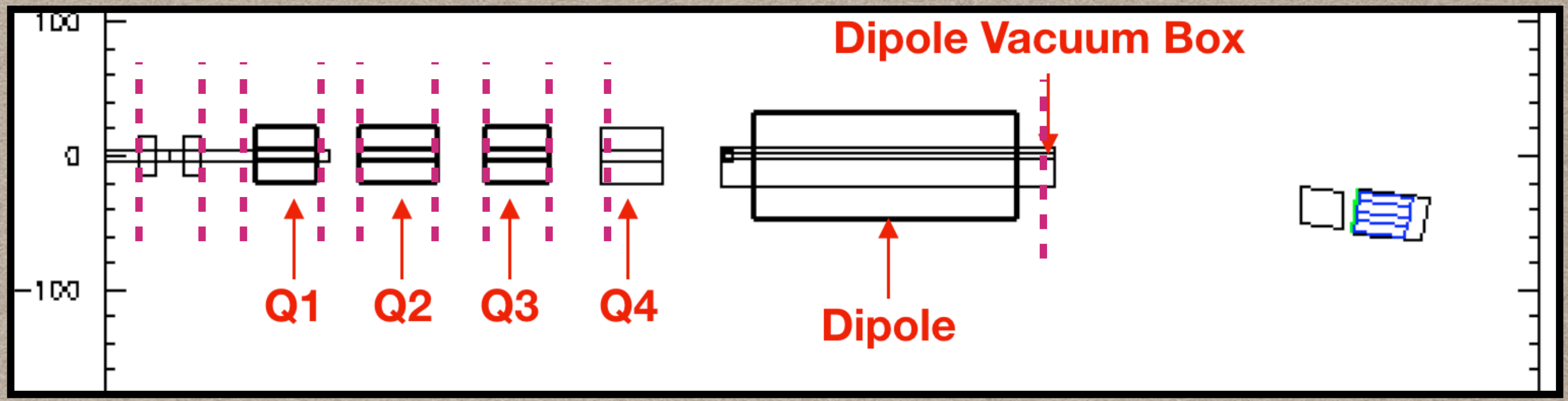
GEANT3 SIMULATION: VALIDATING GEANT4

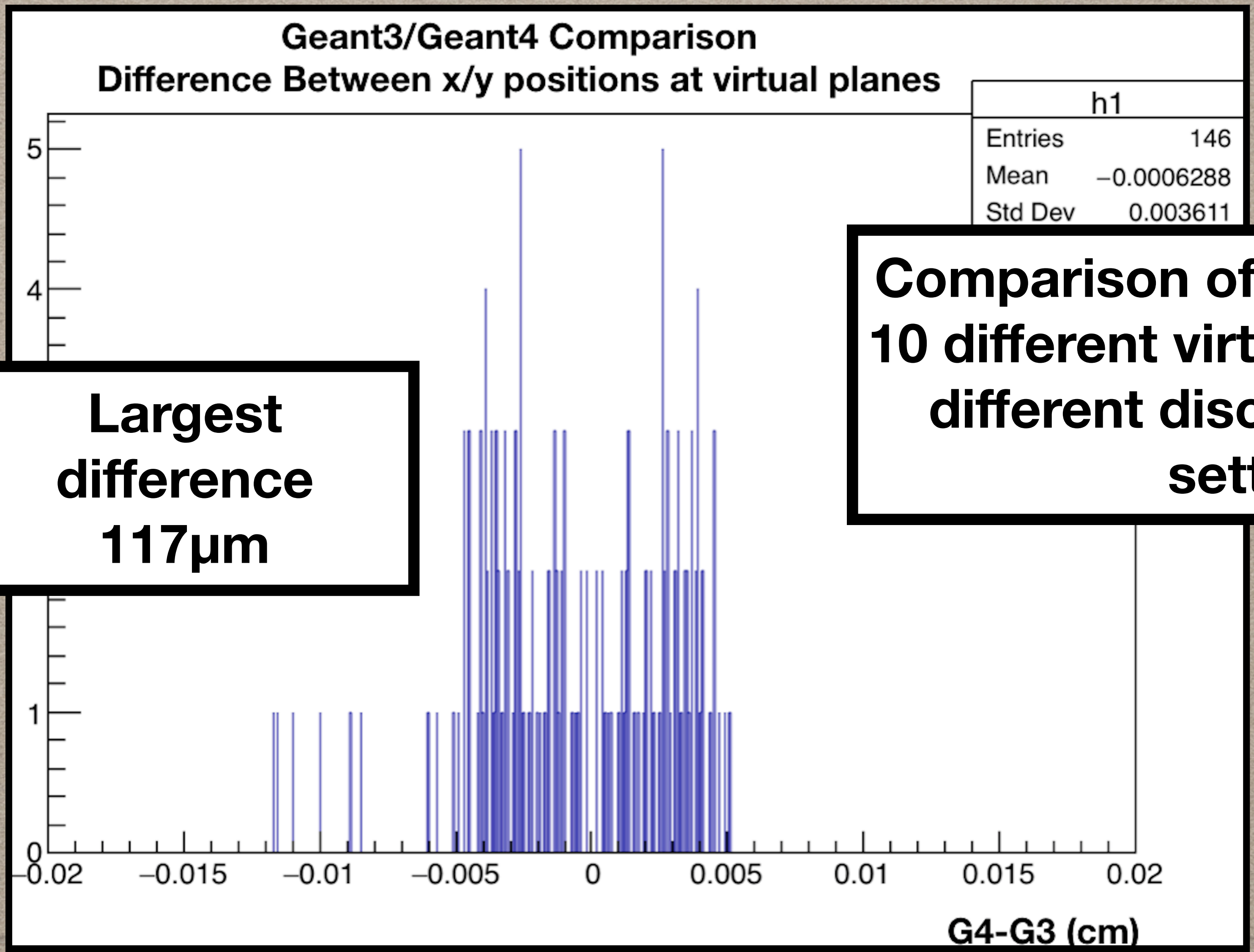
Ray Tracing Comparison



GEANT3 SIMULATION: VALIDATING GEANT4

Ray Tracing Comparison



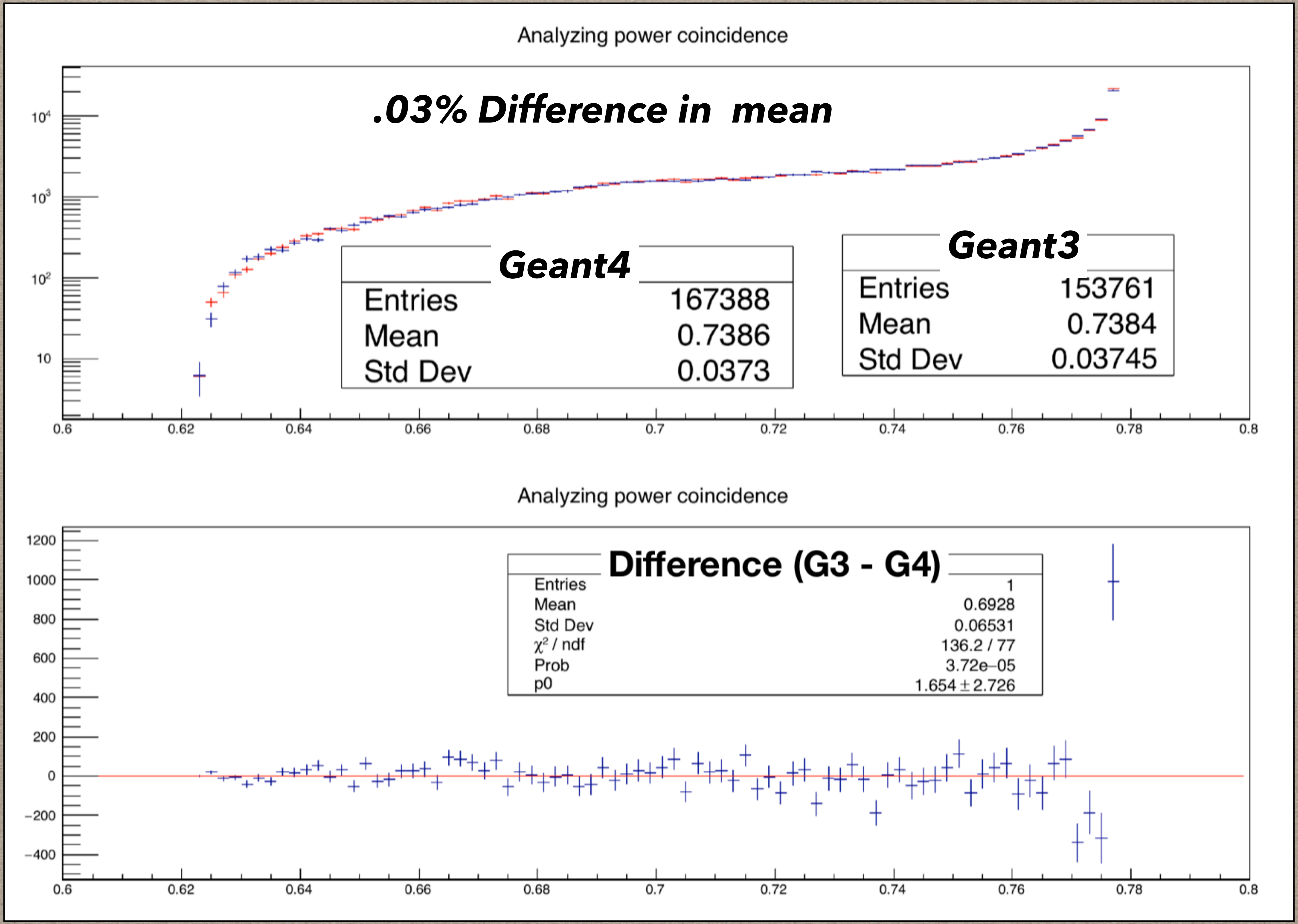


Largest difference 117μm

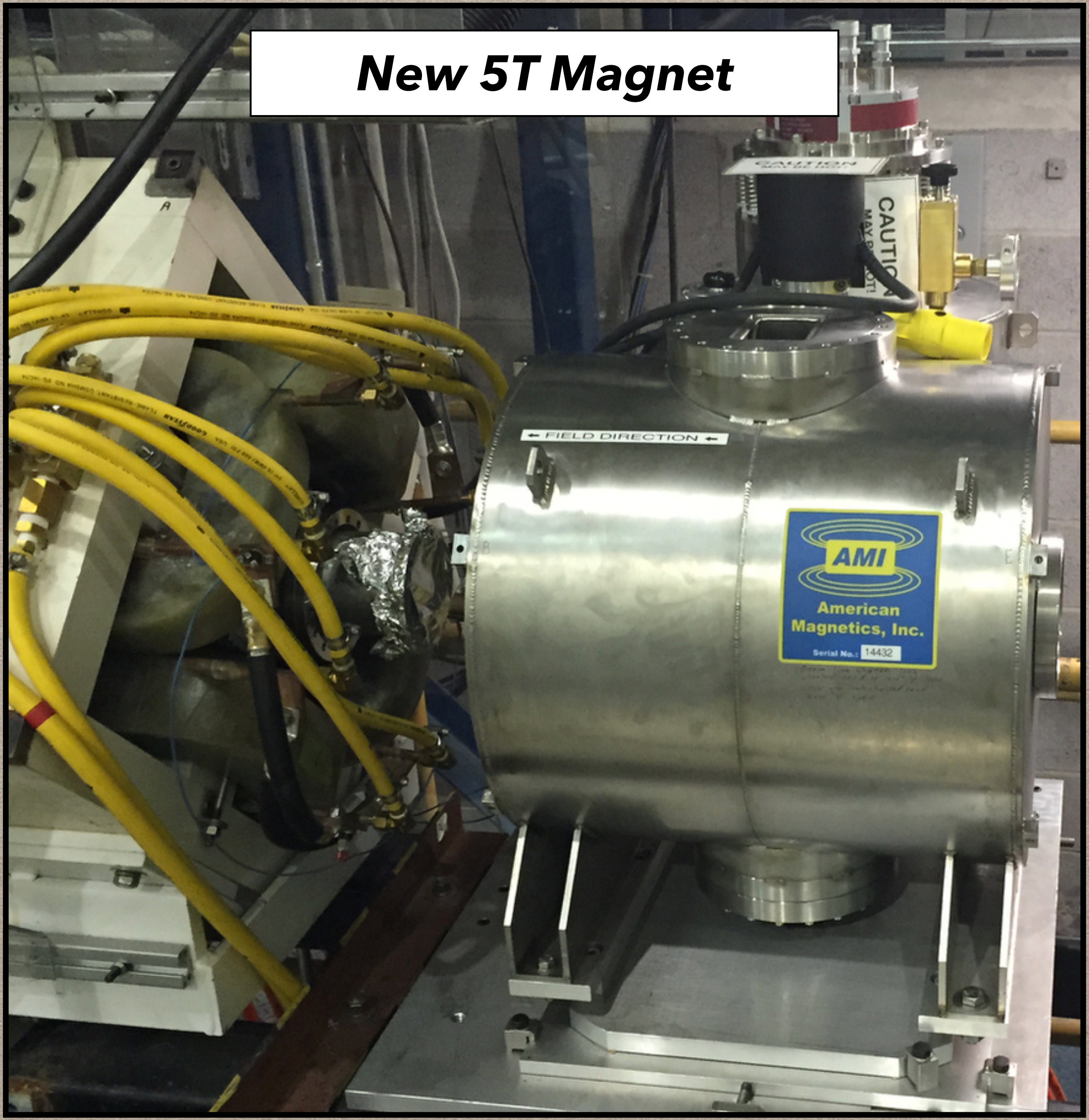
Comparison of x/y positions at 10 different virtual planes and 5 different discrete theta/phi settings

GEANT3 SIMULATION: VALIDATING GEANT4

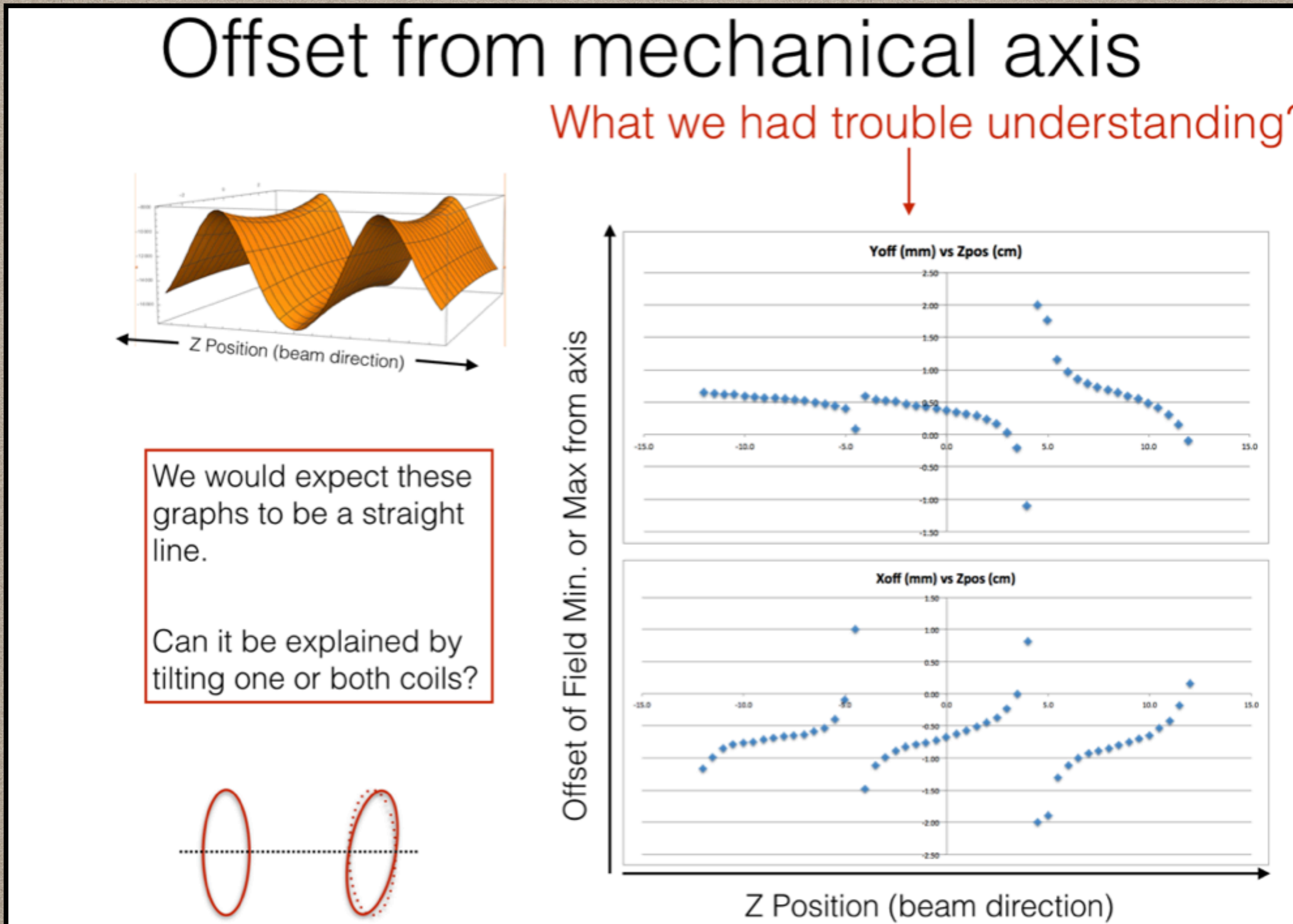
<Azz> Comparison



GEANT3 SIMULATION: TARGET FIELD MAP



GEANT3 SIMULATION: TARGET FIELD MAP



GEANT3 SIMULATION: TARGET FIELD MAP

Data and Theory

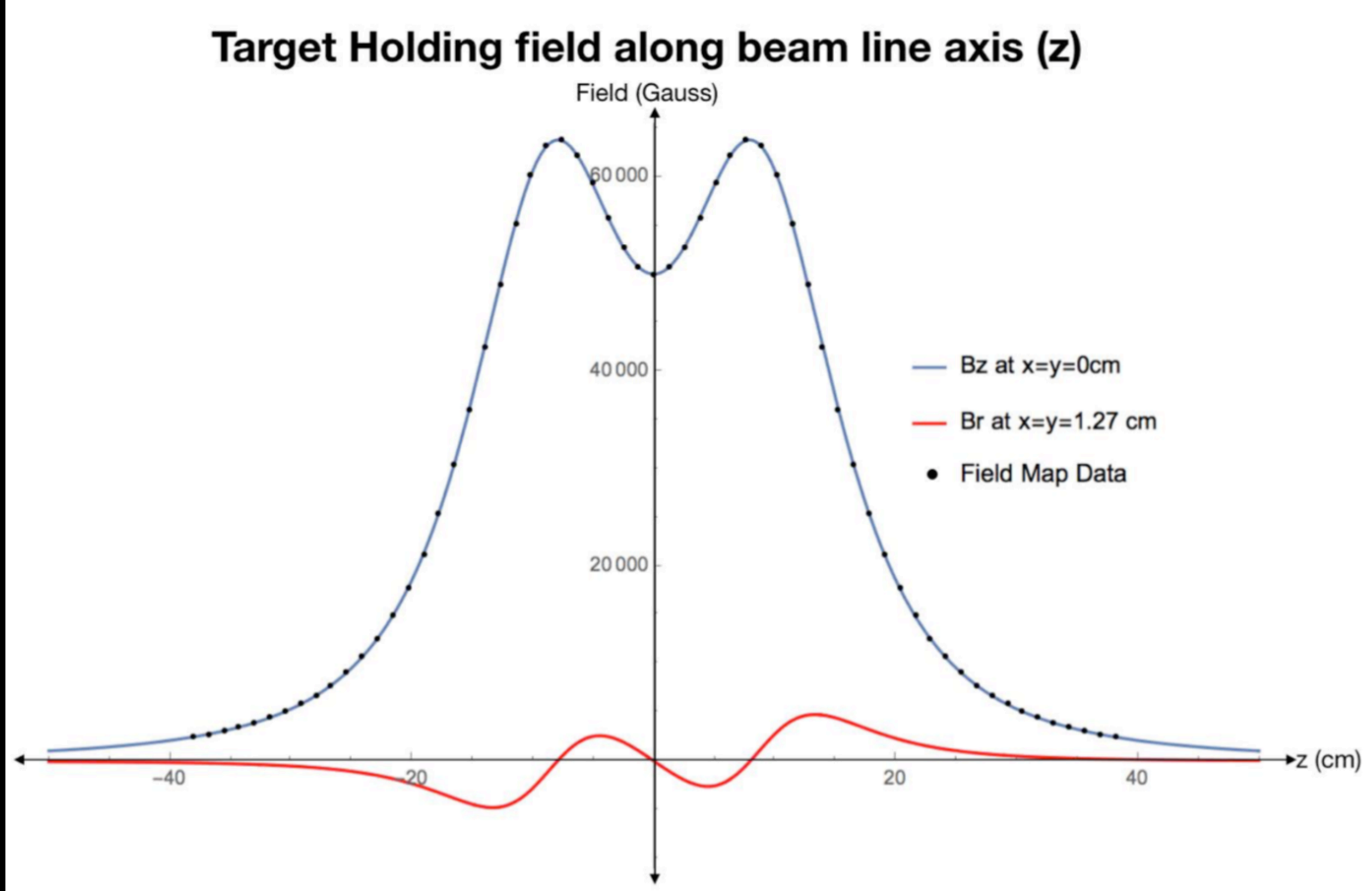
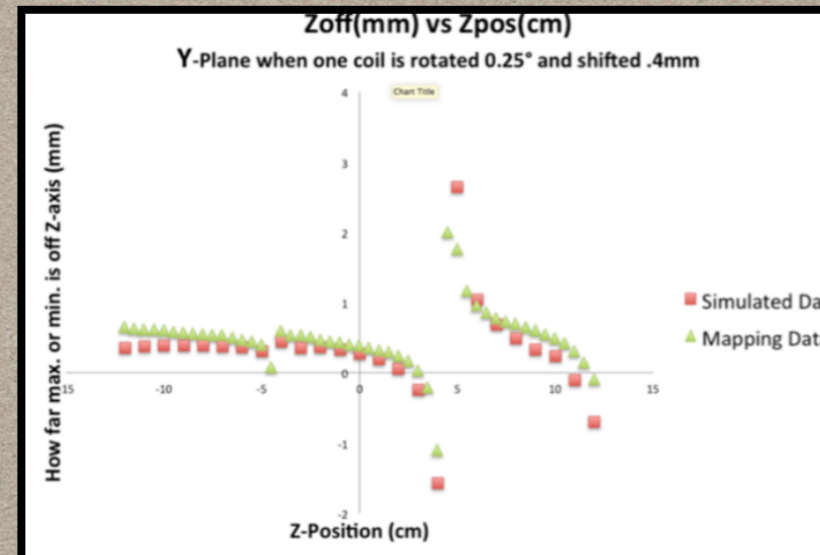
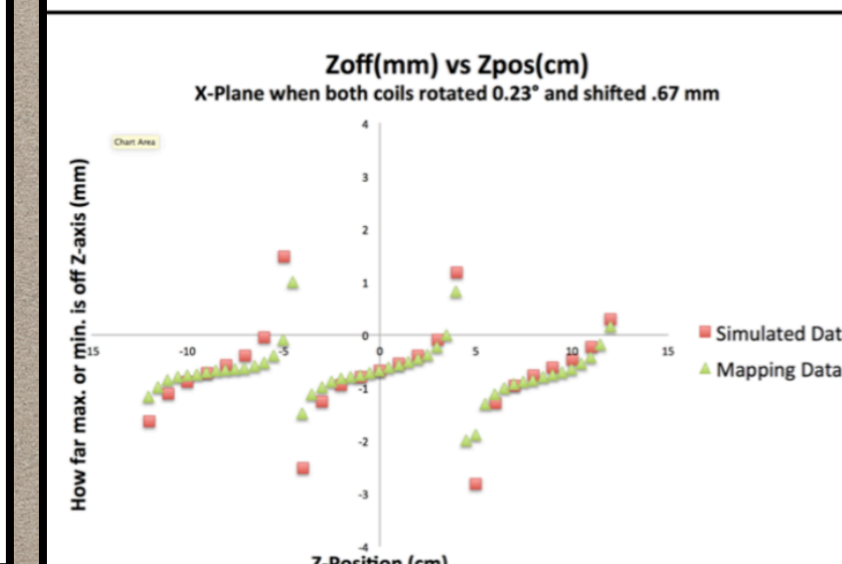


Figure 4.20: Measured data and fit of holding field magnet

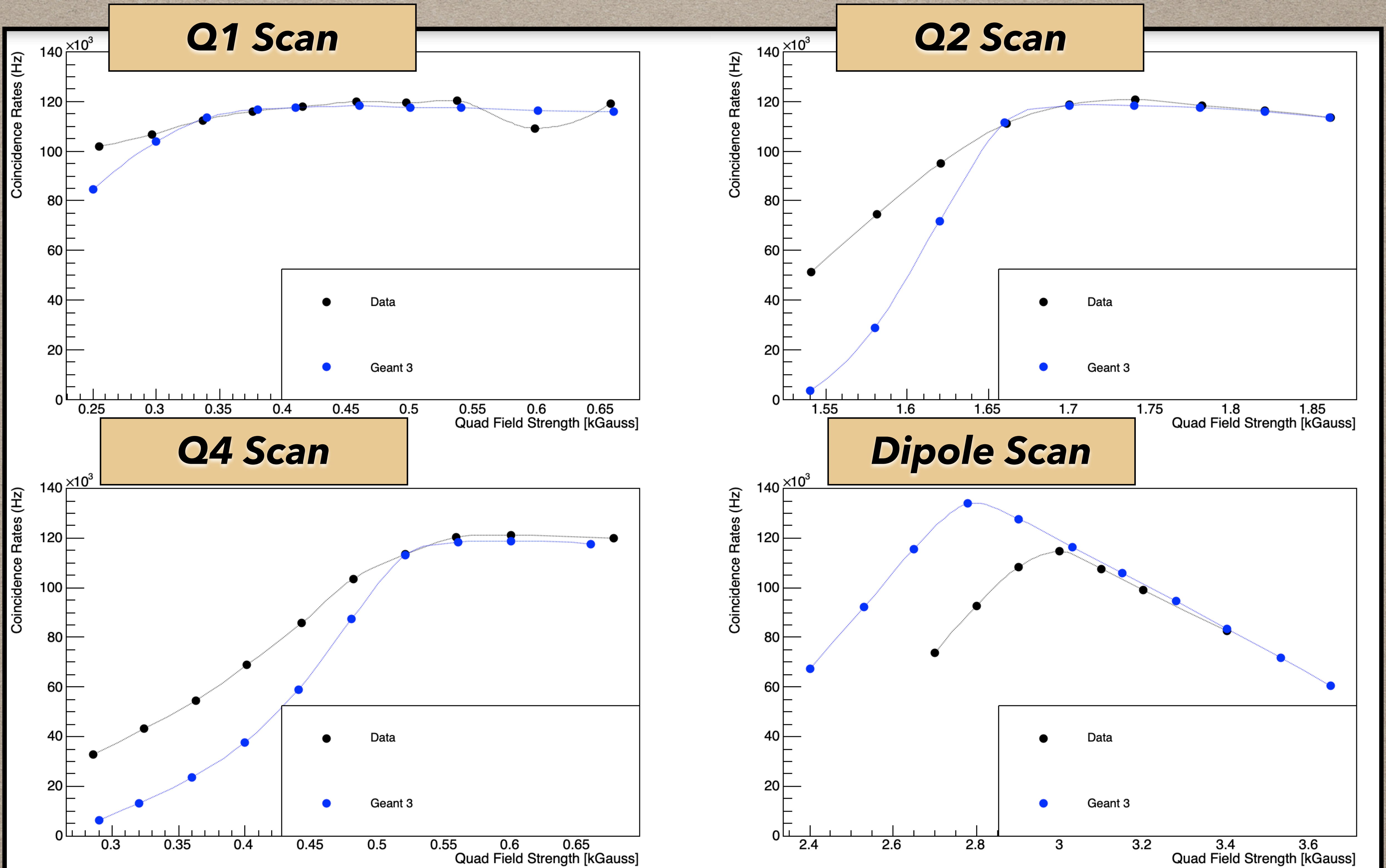
Tilted Coil Calculation
vs
Map Data





GEANT3 SIMULATION: QUAD SCAN DATA

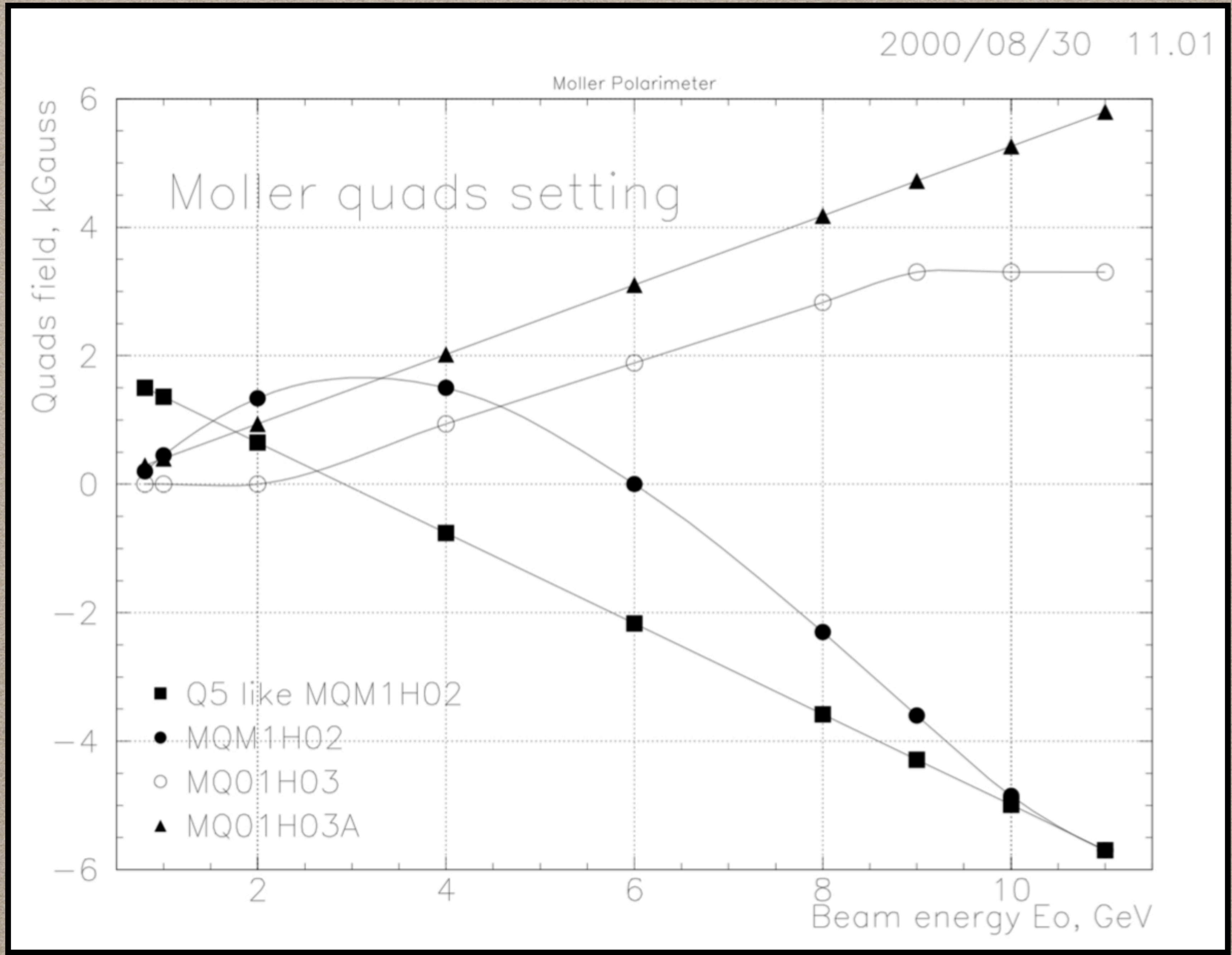
2015 Data Comparison (2.1GeV)



- **OPTICS SOLUTIONS**
  - **PHASE SPACE SCAN**
  - **CREX SOLUTIONS**
  - **PREX SOLUTIONS**

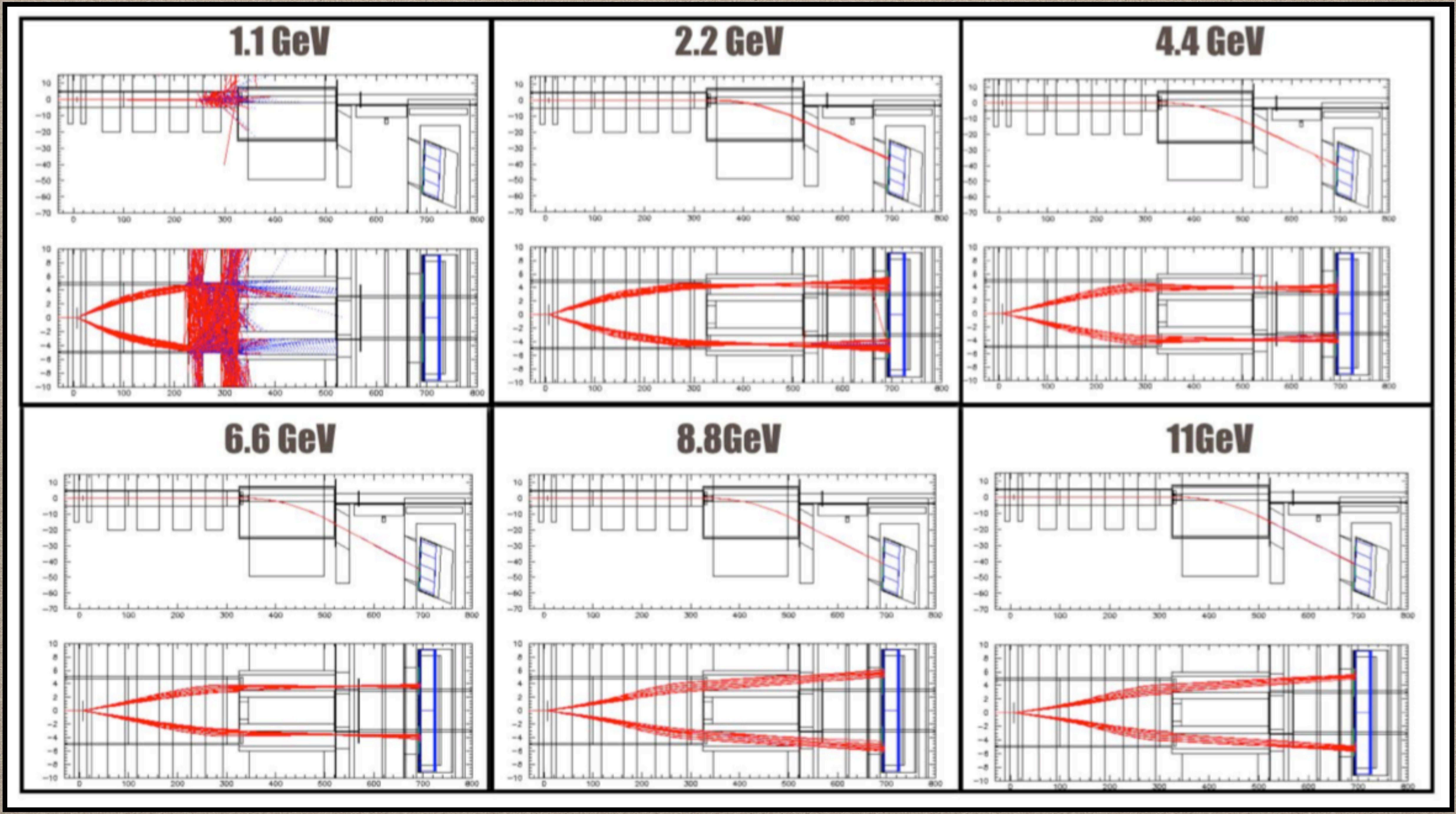
OPTICS SOLUTIONS

Note on Quad. settings for 11 GeV Upgrade



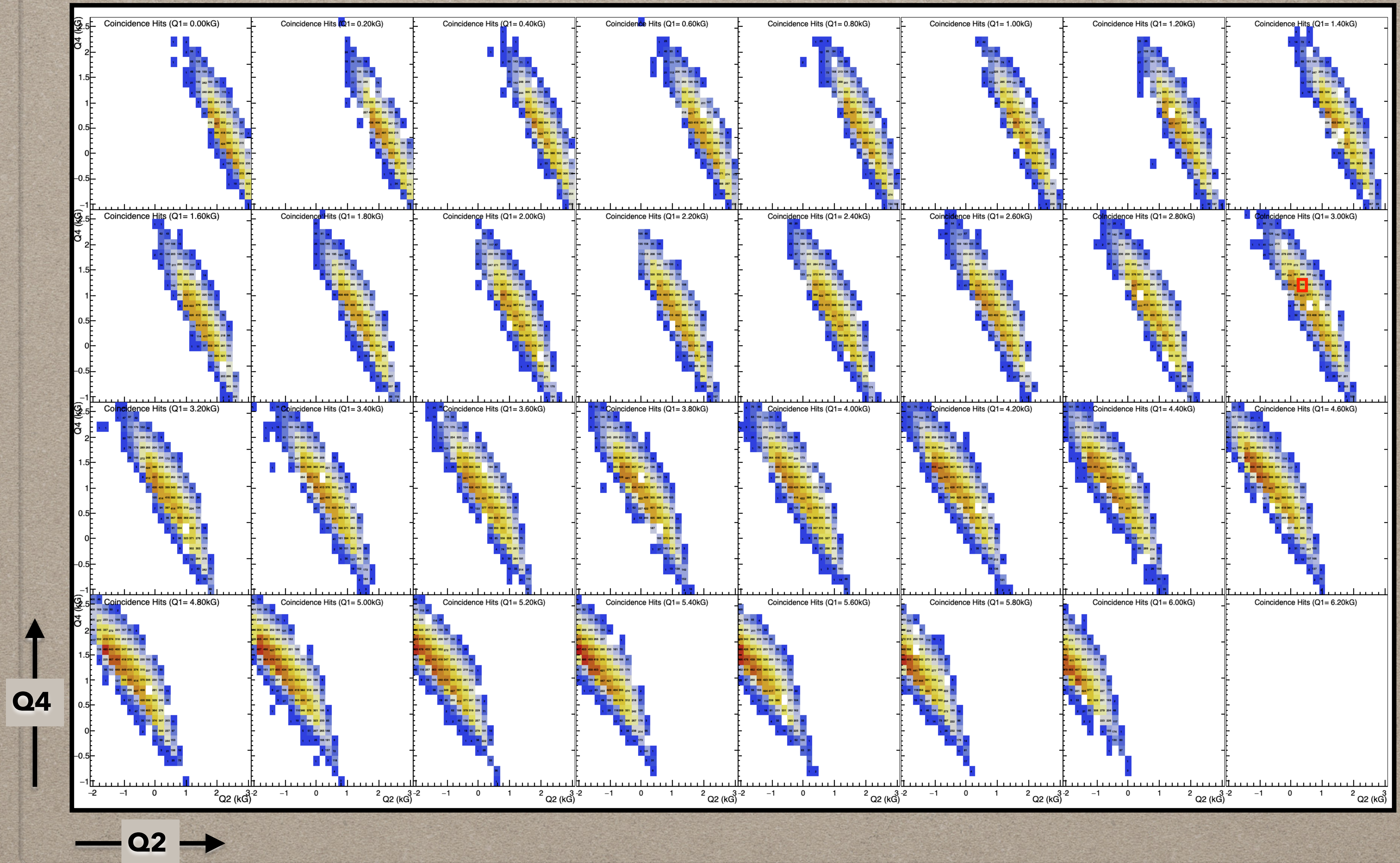
OPTICS SOLUTIONS

Simulation of Documented Quad. Settings



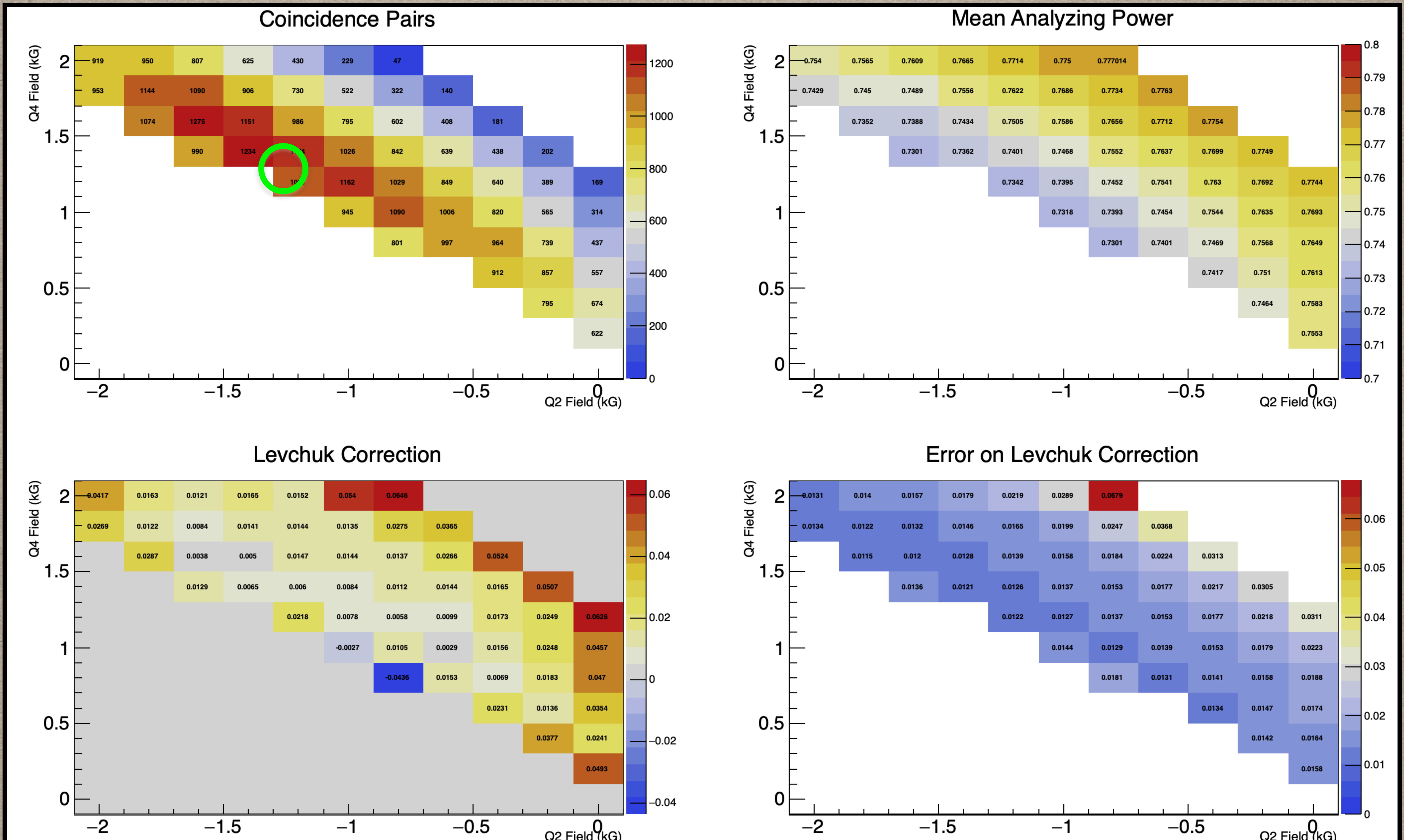
CREX OPTICS SOLUTIONS (2.2 GEV)

Coincidence Hits on Detector at different Q1 settings

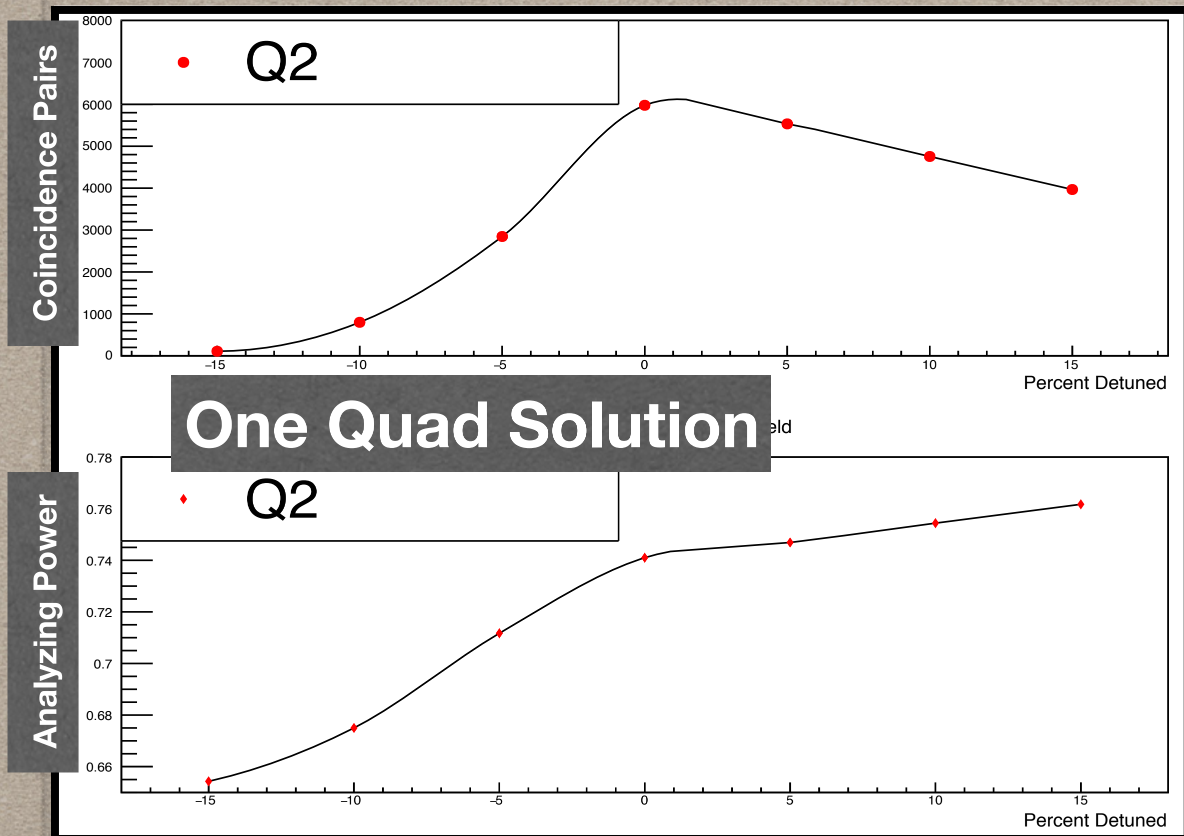


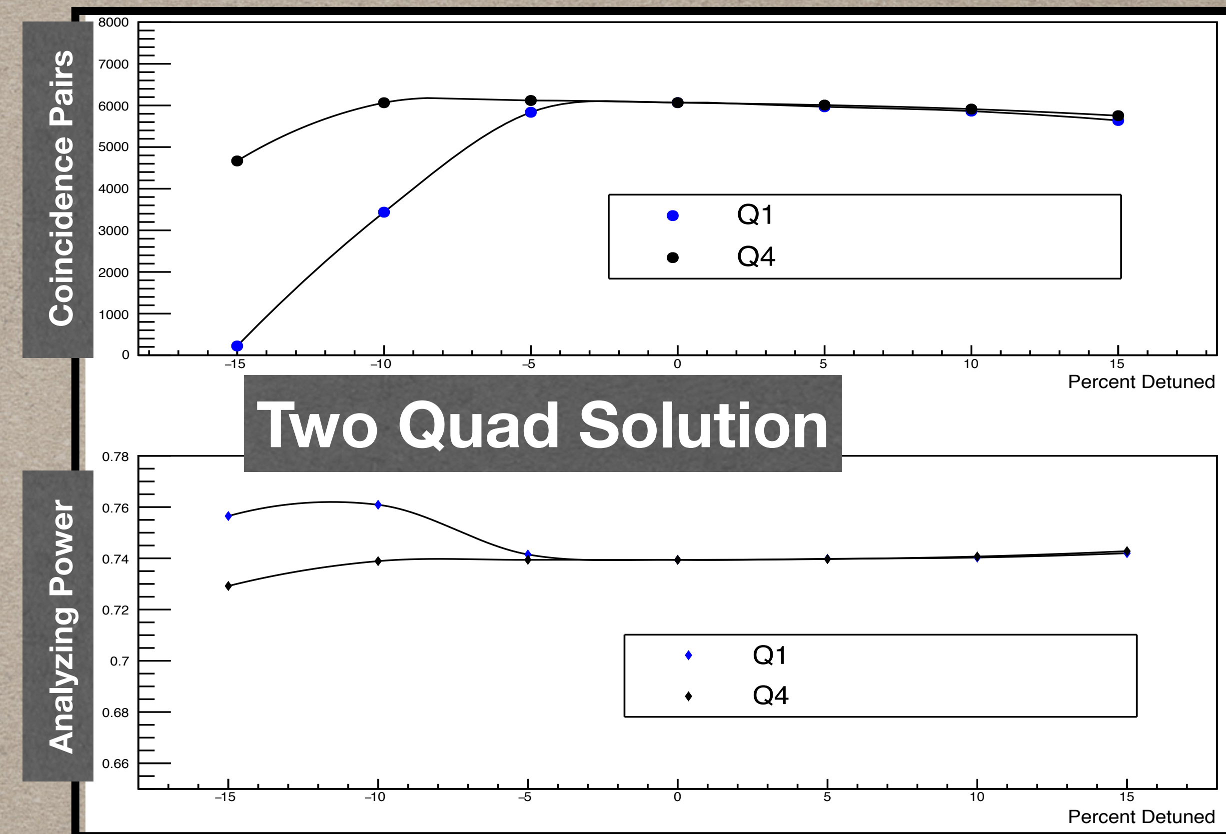
CREX OPTICS SOLUTIONS (2.2 GEV)

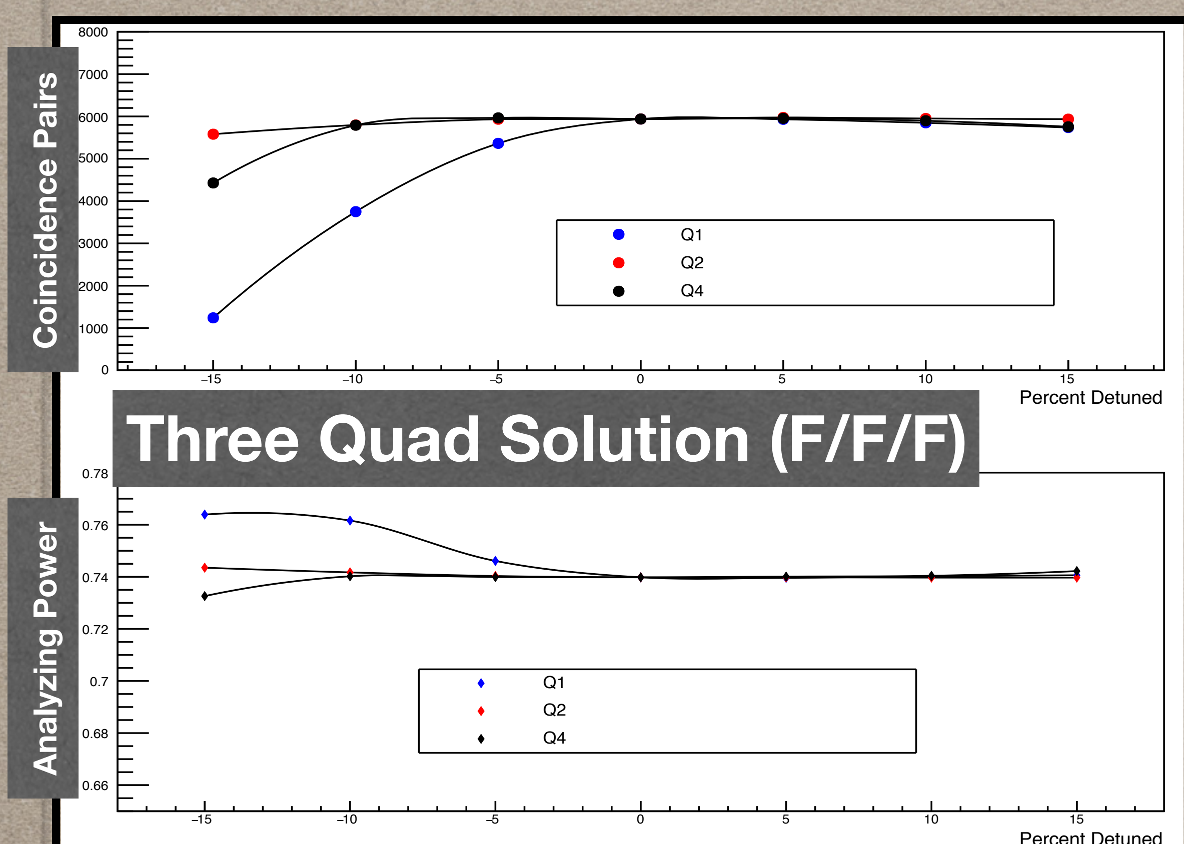
Q1 = 5.0 kG

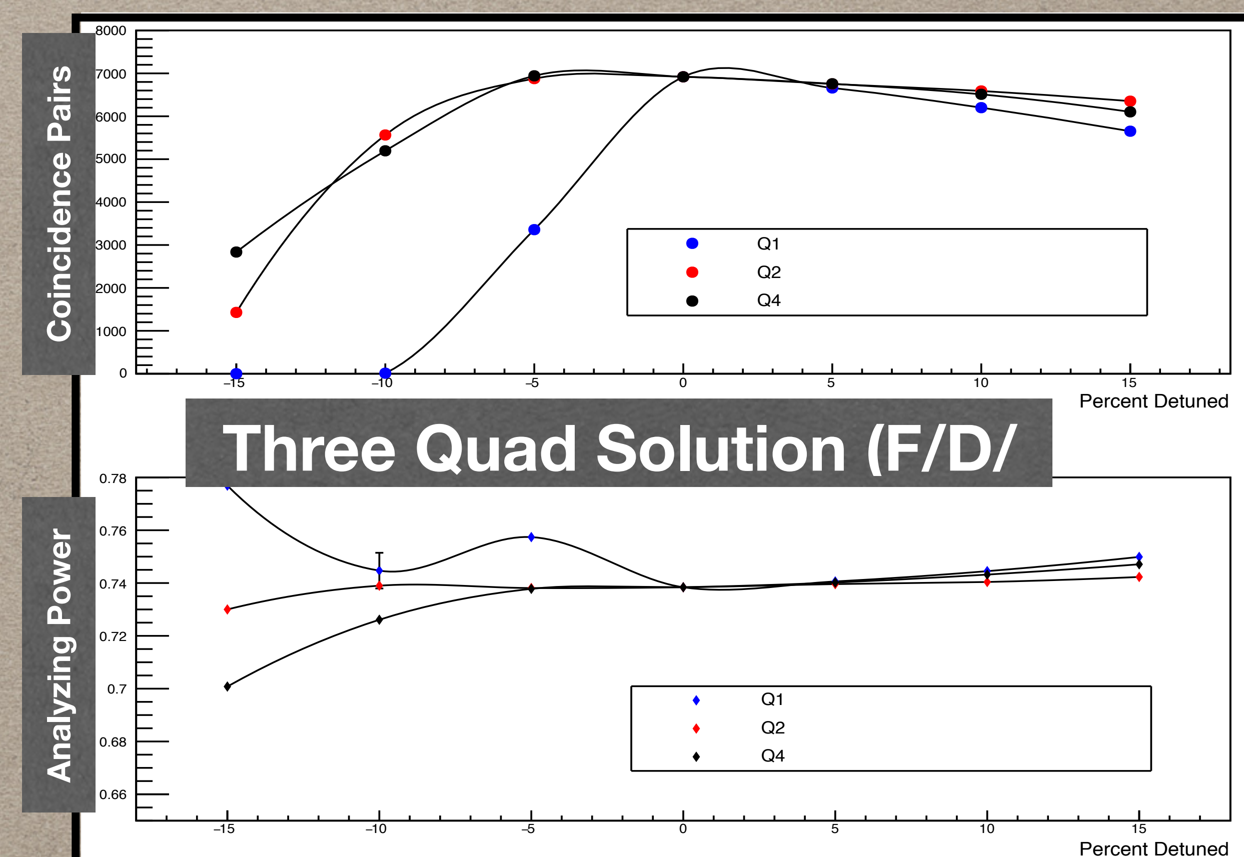


CREX OPTICS SOLUTIONS (2.2 GEV)

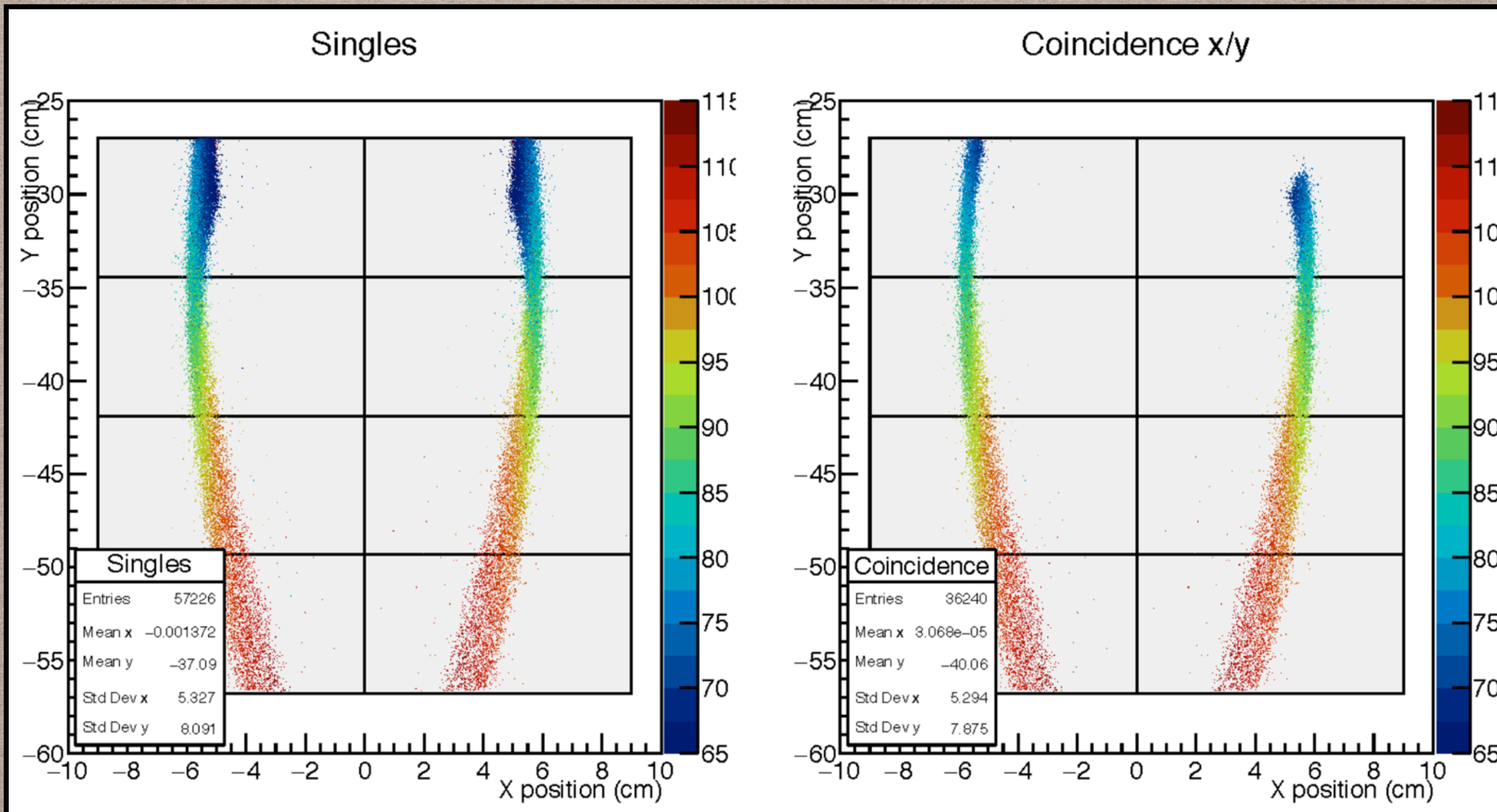






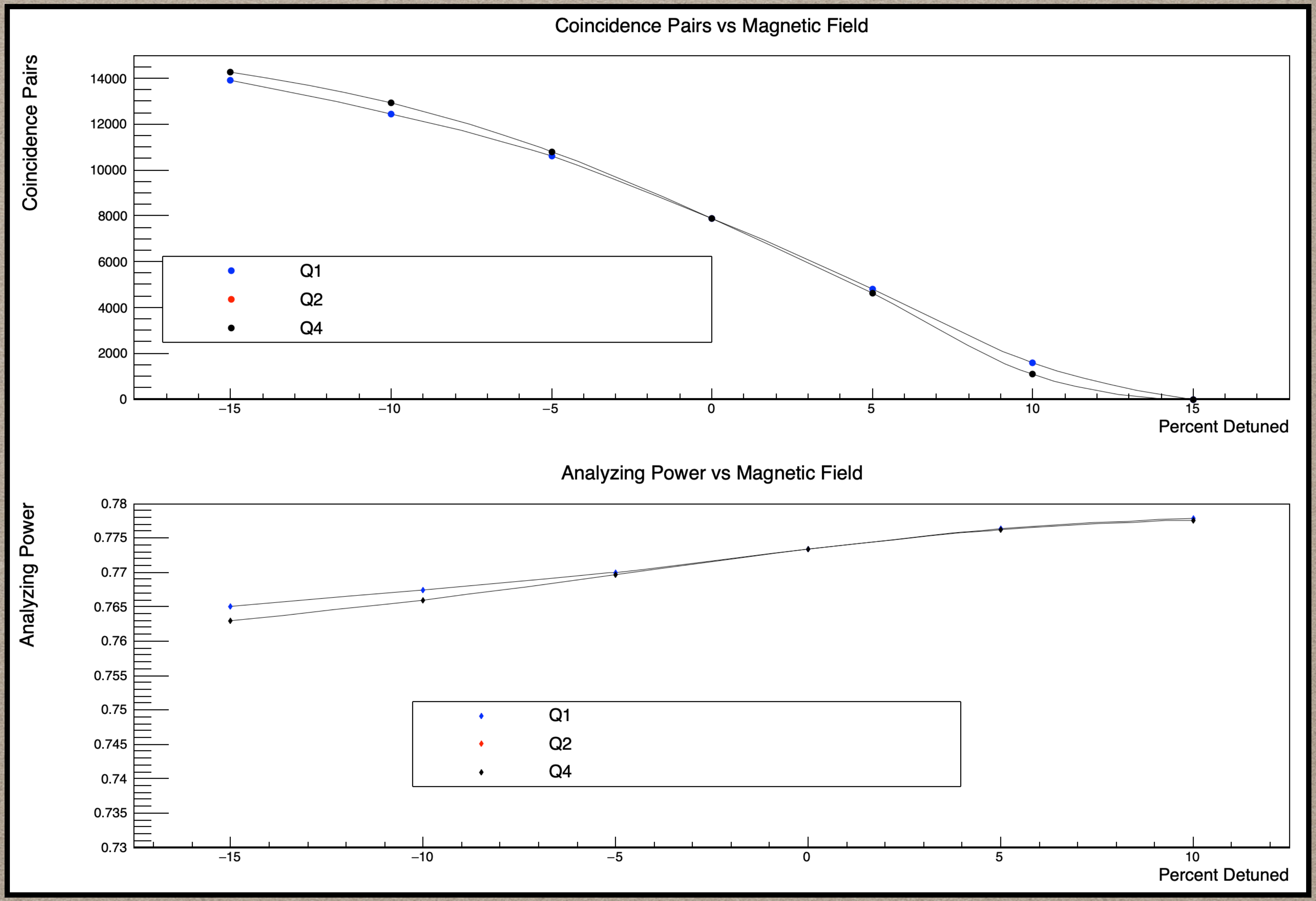


CREX OPTICS SOLUTIONS (2.2 GEV)

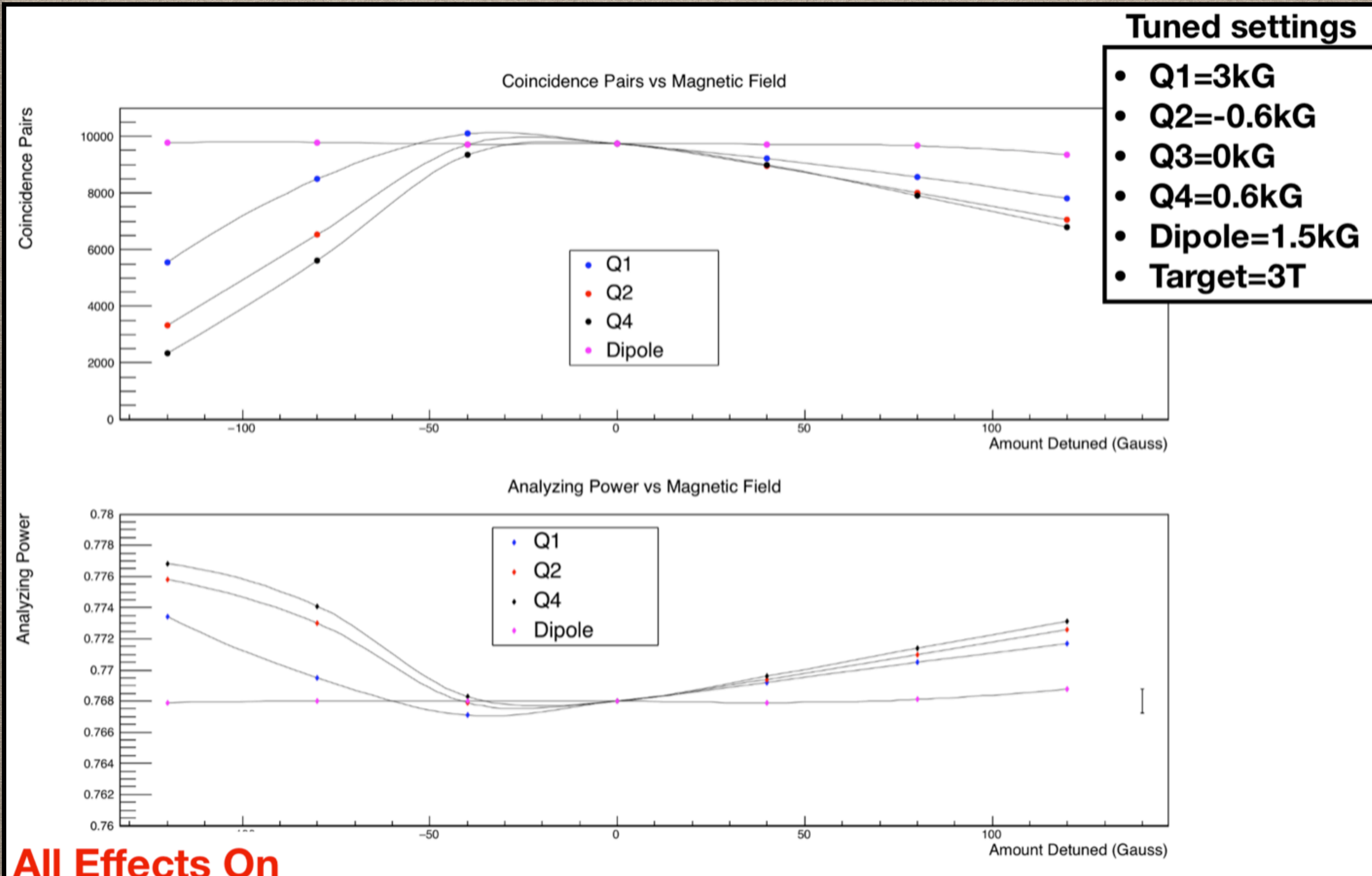


CREX OPTICS SOLUTIONS (2.2 GEV)

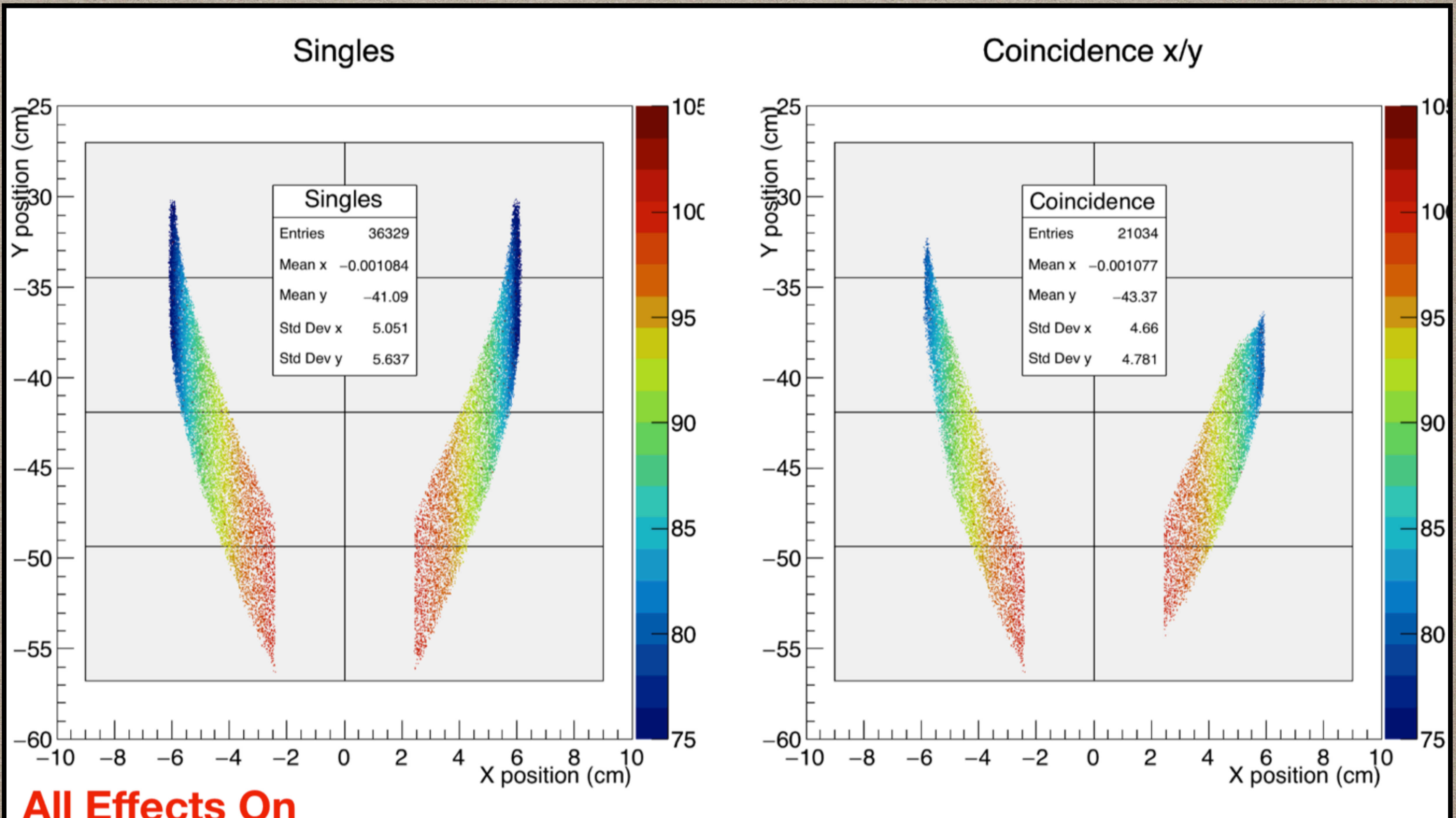
Solution where electrons are not hitting detector shielding box



PREX OPTICS SOLUTIONS (0.95 GEV)



PREX OPTICS SOLUTIONS (0.95 GEV)



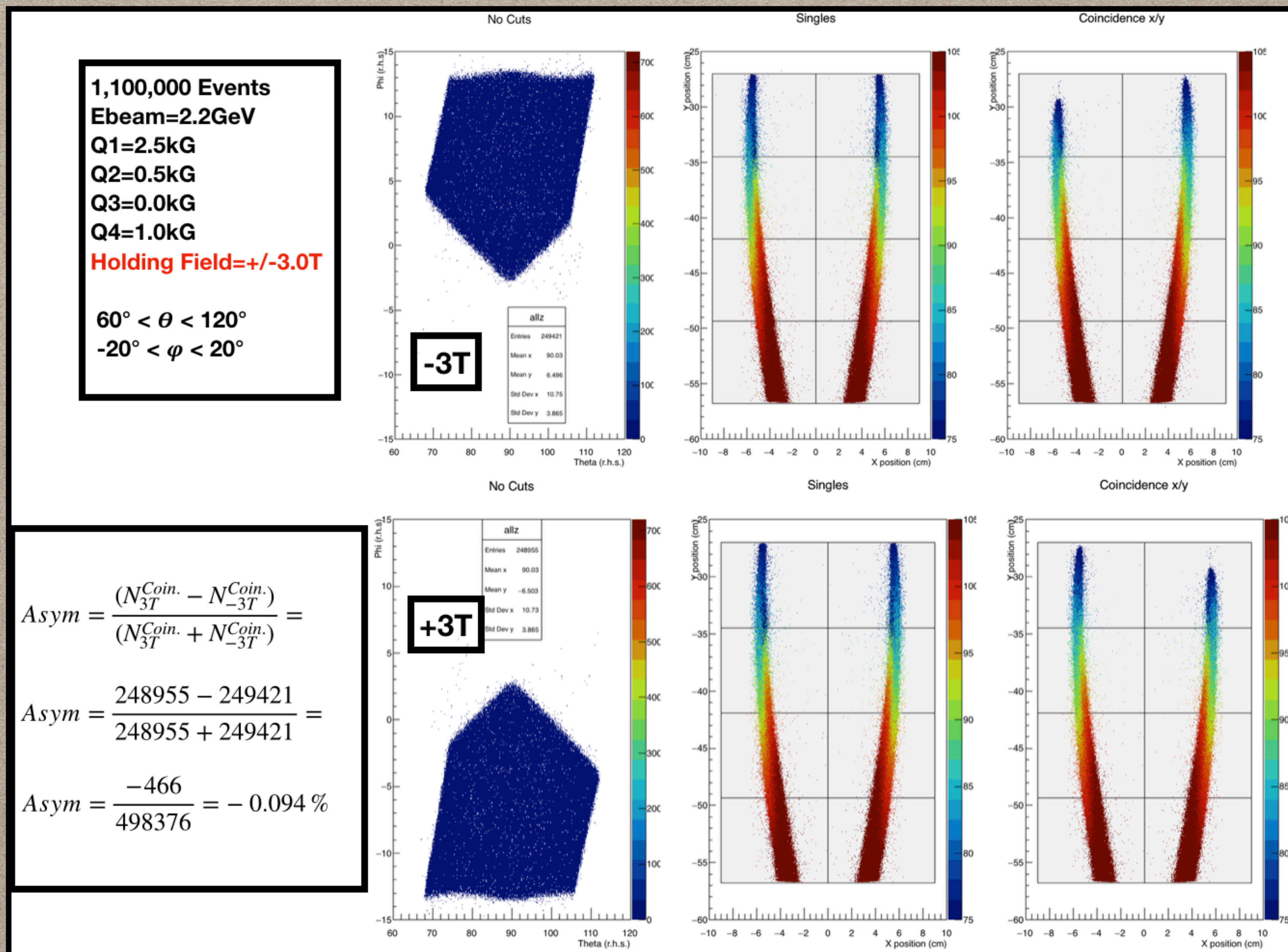
- **OUTLOOK**
  - “COMMISIONING PLAN” FOR CREX
  - DAQ ANALYSIS IMPROVEMENTS
  - CURRENT READINESS AND FUTURE WORK

OUTLOOK: POLARIMETER COMMISIONING PLAN

Commisioning plan almost finalized for upcoming shifts after APEX

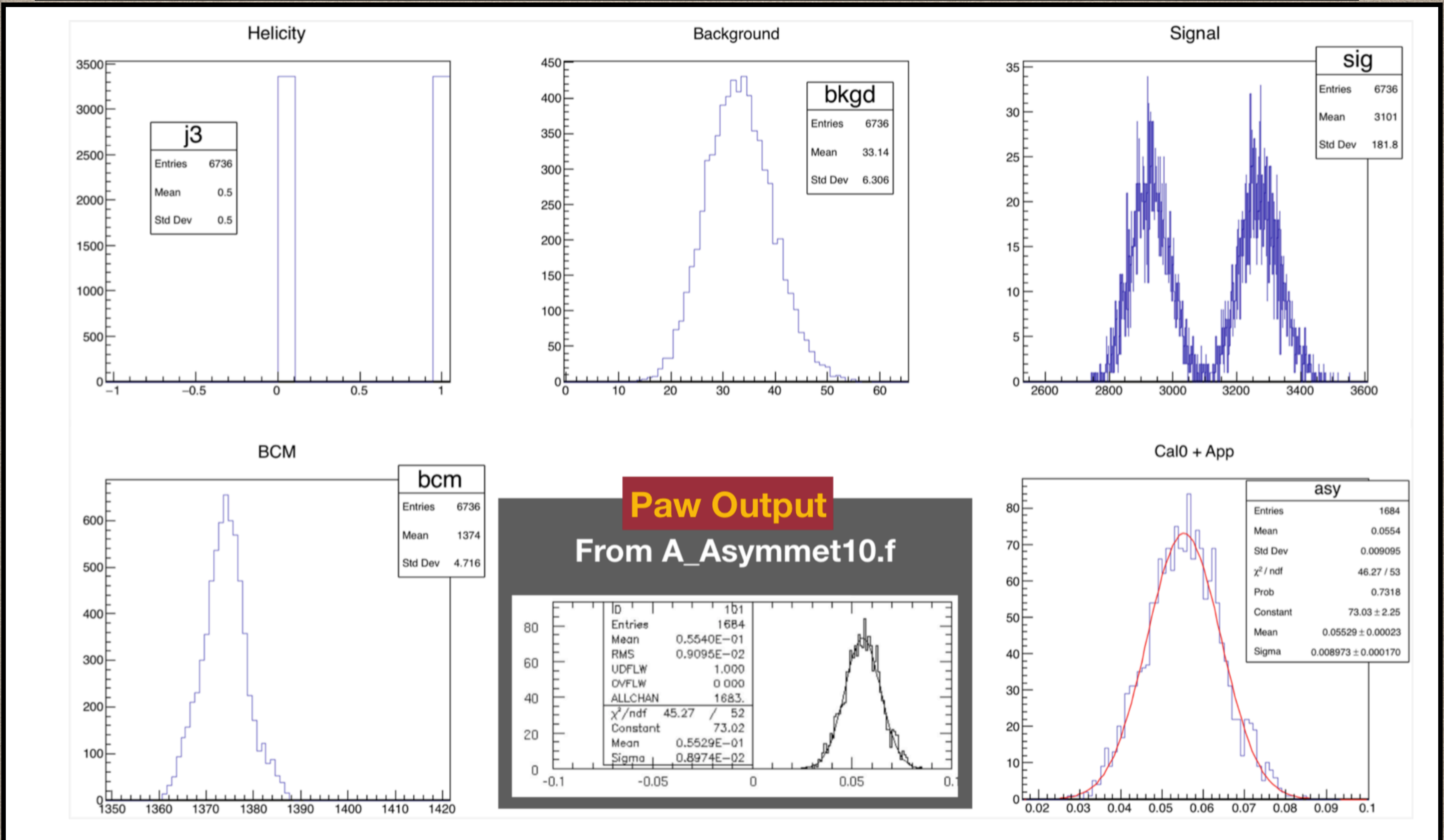
- **Superconducting Target Magnet alignment (Yves)**
- **Detector Thresholds and HV tuning**
- **Target Foil Centering test**
- **Quad and Dipole Scans**
- **Target Saturation Study**
- **Holding field Reversal Study**

OUTLOOK: POLARIMETER COMMISIONING PLAN



OUTLOOK: DATA ANALYSIS

Data Anaylsis Scripts being developed using C++ and ROOT



PRECISION MØLLER POLARIMETRY

- **Completed Work**
  - Target polarization studies for ~1.0% polarimetry
  - New 5T Magnet Mapped, analyzed, and incorporated in simulations
  - New target motion system installed
  - New Geant3 simulation expertise
  - "Brute Force" polarimetry measurements for DVCS
  - TOSCA maps created and implemented in GEANT4
- **Nearly Completed (~ weeks) Work**
  - Geant3 documentation and how-to's
  - GEANT4 simulation
  - Final optics settings for CREX and PREX-II
  - Commisioning plan for Møller polarimeter
  - Survey results (Geometry in simulation not correct)
- **Future Work**
  - Target polarization studies for <0.5% polarimetry
  - DAQ improvements (FADC system, new PMT's being purchased,…)
  - Rewrite analysis software (C++)

PRECISION MØLLER POLARIMETRY SUMMARY AND CONCLUSIONS

- **The newly upgraded Møller polarimeter in Hall A is on track to be ready to meet upcoming precision requirements for CREX and PREX-II**
- **Work needs to be done to limit systematic errors and reach the goal of <0.5% precision on beam polarization measurements**

PRECISION MØLLER POLARIMETRY

SPECIAL ACKNOWLEDGMENTS AND THANKS TO:

- Jim Napolitano
- Don Jones
- James Wilhemi
- Javier Gomez
- Ethan Becker
- Dave Gaskell
- Simona Malace
- Sasha Glamazdi
- Roman Pomatsalyuk
- Kent Paschke
- Sanghwa Park
- Eric King
- Paul Soder

And funding from The National Science Fondation

NSF

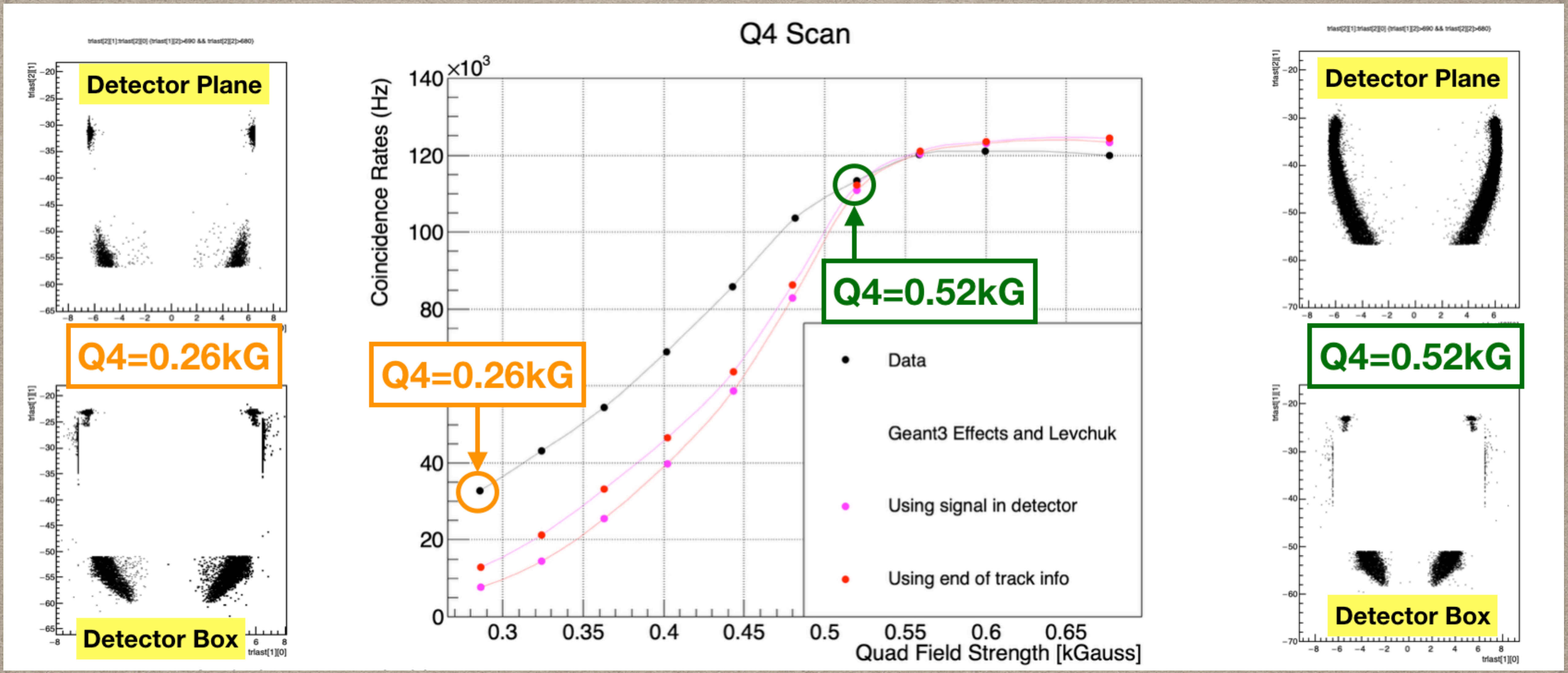
ХФТИ

Syracuse University

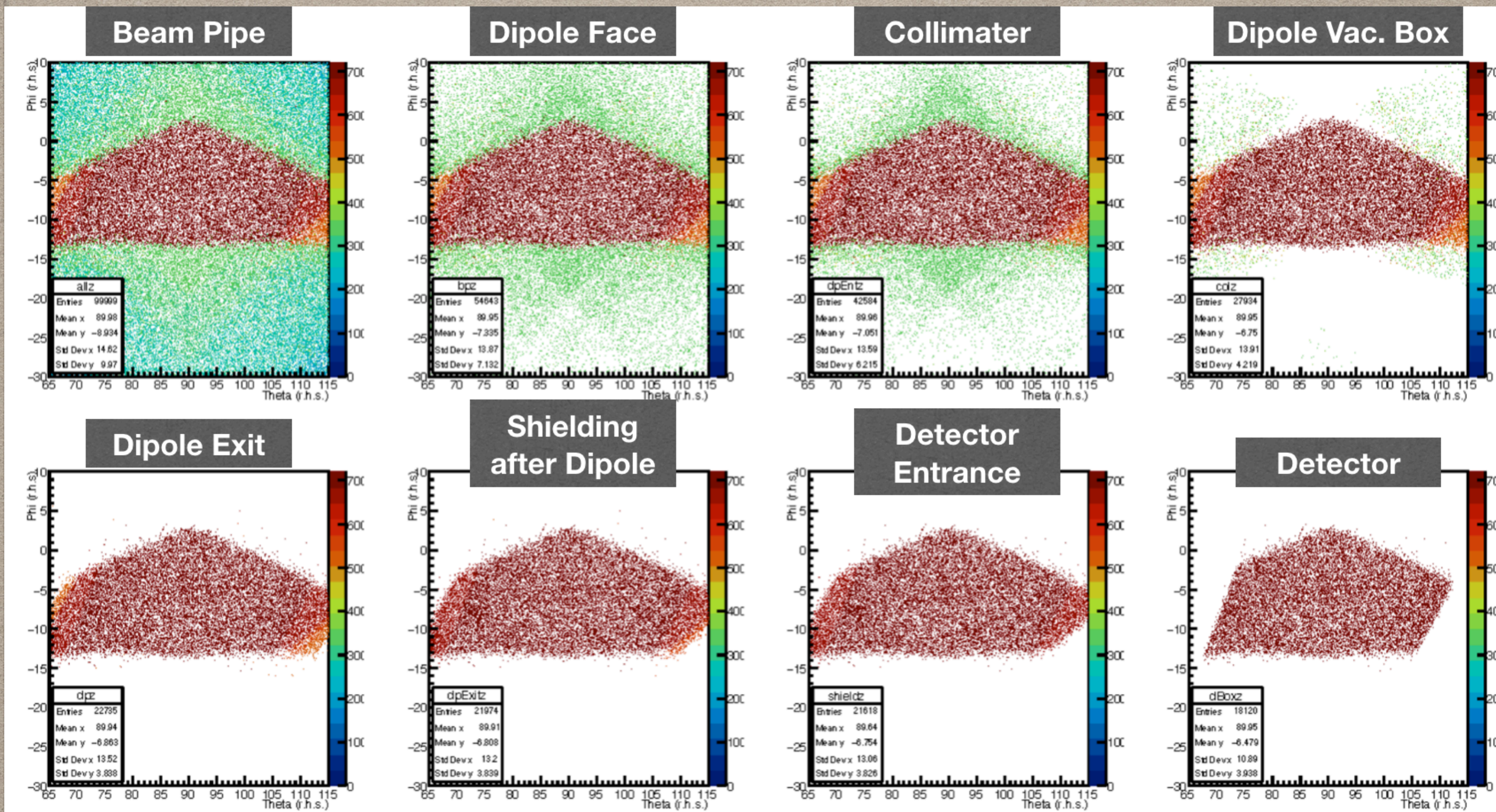
Jefferson Lab

BACK UP

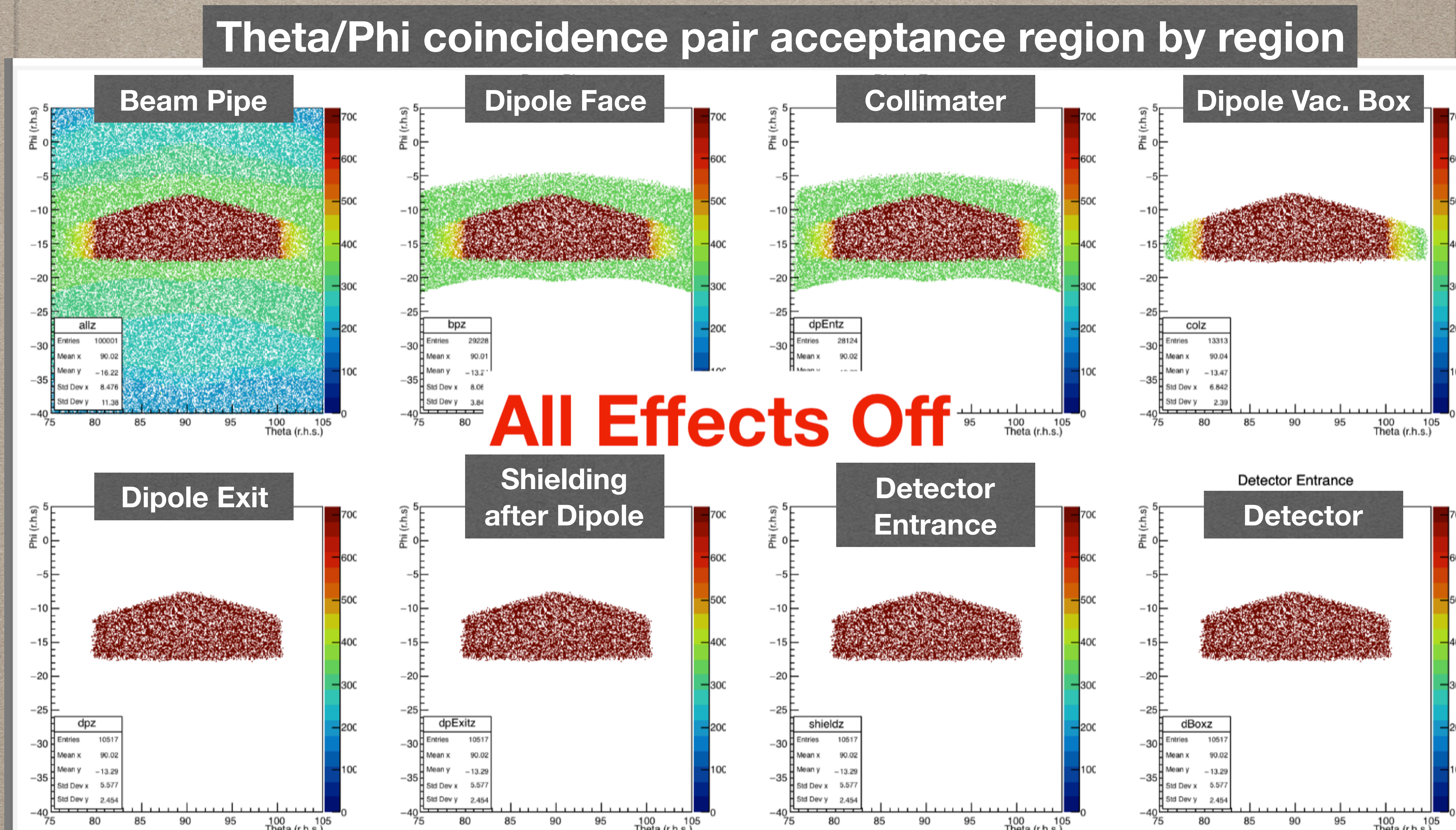
2015 QUAD SCAN DATA (2.1 GEV)



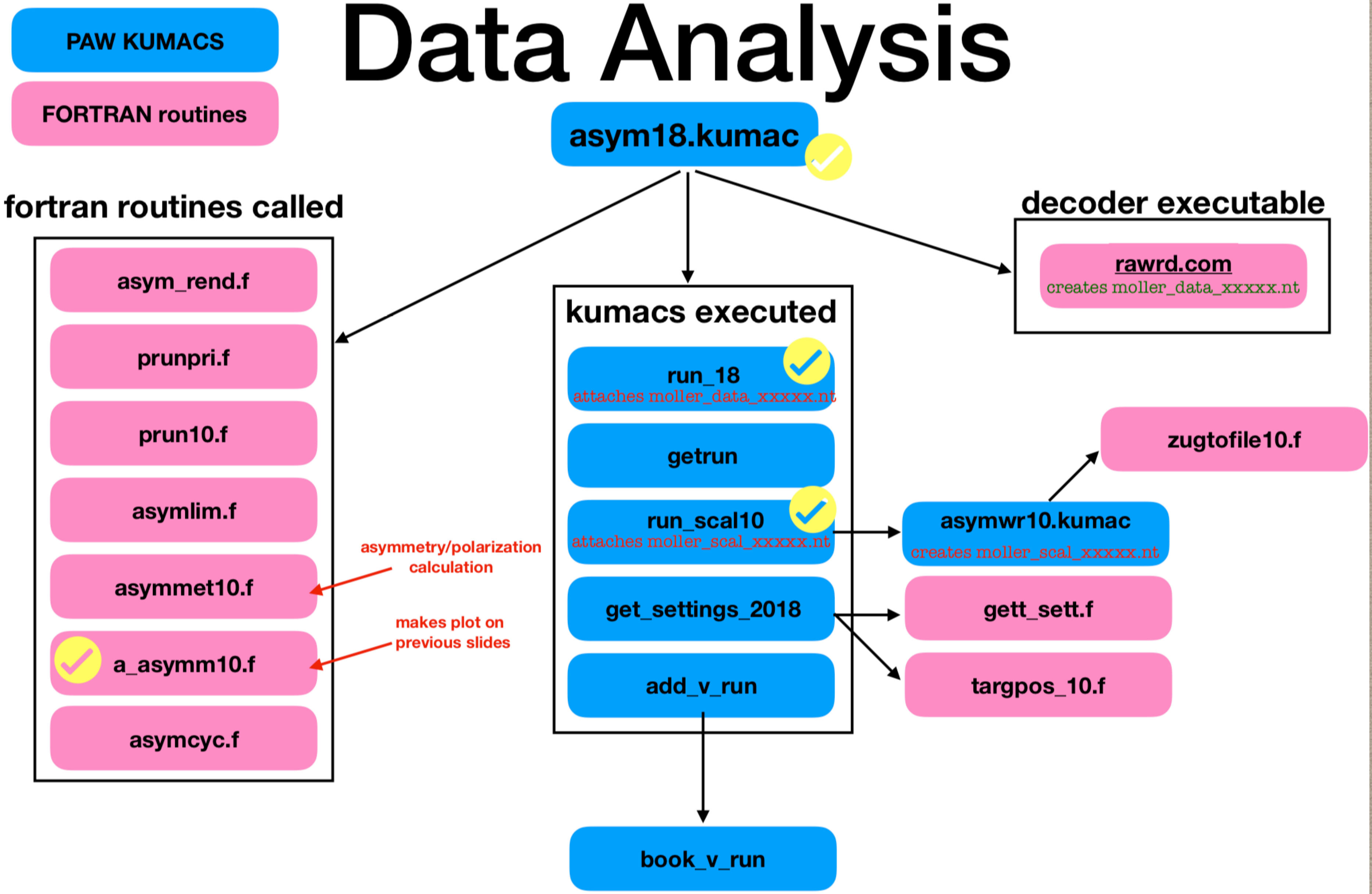
CREX OPTICS SOLUTIONS (2.2 GEV)



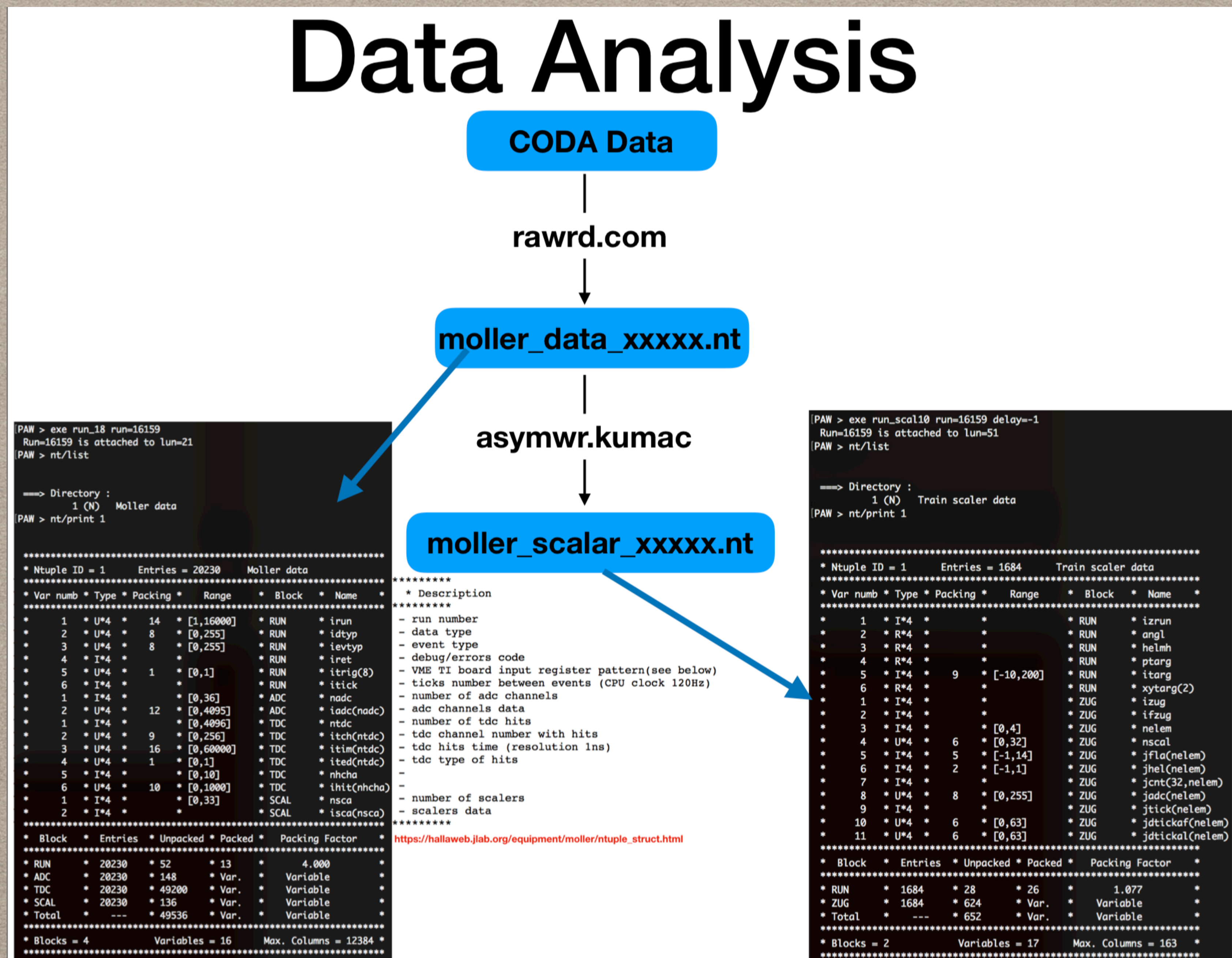
PREX OPTICS SOLUTIONS (0.95 GEV)



Data Analysis

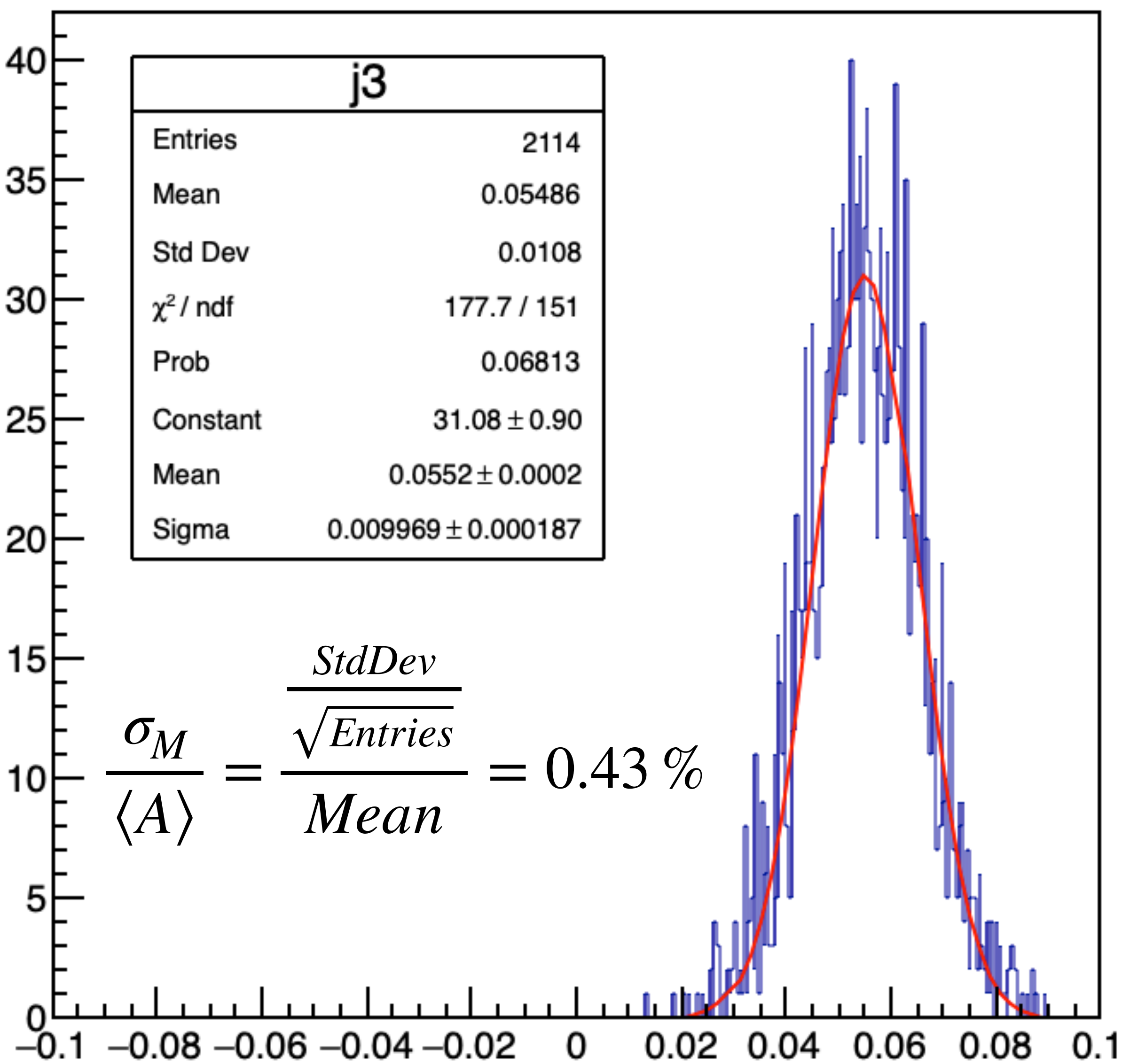


Cameron Clarke began detailing code here
https://hallaweb.jlab.org/wiki/index.php/Old_MolPol_DAQ_Analysis

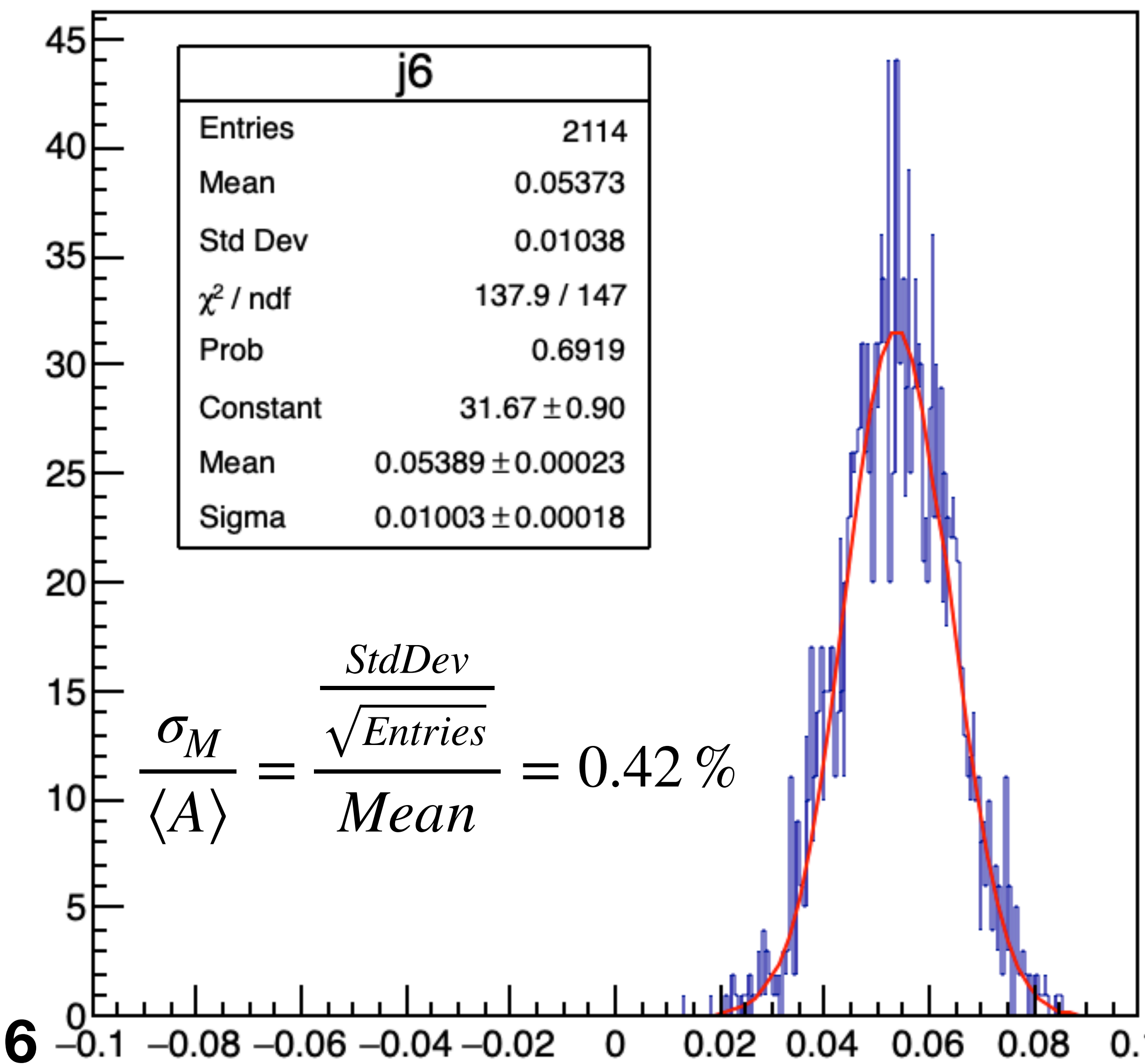

Data Analysis
CODA Data
rawrd.com
moller_data_xxxxx.nt
asymwr.kumac
moller_scalar_xxxxx.nt
[PAW > exe run_18 run=16159
Run=16159 is attached to lun=21
[PAW > nt/list
===> Directory :
1 (N) Moller data
[PAW > nt/print 1
* Ntuple ID = 1 Entries = 20230 Moller data
* Var numb * Type * Packing * Range * Block * Name *
* 1 * U*4 * 14 * [1,16000] * RUN * irun
* 2 * U*4 * 8 * [0,255] * RUN * idtyp
* 3 * U*4 * 8 * [0,255] * RUN * ievtyp
* 4 * I*4 * * * RUN * iret
* 5 * U*4 * 1 * [0,1] * RUN * itrig(8)
* 6 * I*4 * * * RUN * itick
* 1 * I*4 * * [0,36] * ADC * nadc
* 2 * U*4 * 12 * [0,4095] * ADC * iadc(nadc)
* 1 * I*4 * * [0,4096] * TDC * ntdc
* 2 * U*4 * 9 * [0,256] * TDC * itch(ntdc)
* 3 * U*4 * 16 * [0,60000] * TDC * itim(ntdc)
* 4 * U*4 * 1 * [0,1] * TDC * ited(ntdc)
* 5 * I*4 * * [0,10] * TDC * nhcha
* 6 * U*4 * 10 * [0,1000] * TDC * ihit(nhcha)
* 1 * I*4 * * [0,33] * SCAL * nsca
* 2 * I*4 * * * SCAL * isca(nsca)
* Block * Entries * Unpacked * Packed * Packing Factor *
* RUN * 20230 * 52 * 13 * 4.000 *
* ADC * 20230 * 148 * Var. * Variable *
* TDC * 20230 * 49200 * Var. * Variable *
* SCAL * 20230 * 136 * Var. * Variable *
* Total * --- * 49536 * Var. * Variable *
* Blocks = 4 Variables = 16 Max. Columns = 12384 *
* Description
- run number
- data type
- event type
- debug/errors code
- VME TI board input register pattern(see below)
- ticks number between events (CPU clock 120Hz)
- number of adc channels
- adc channels data
- number of tdc hits
- tdc channel number with hits
- tdc hits time (resolution 1ns)
- tdc type of hits
- number of scalers
- scalers data
https://hallaweb.jlab.org/equipment/moller/ntuple_struct.html
[PAW > exe run_scal10 run=16159 delay=-1
Run=16159 is attached to lun=51
[PAW > nt/list
===> Directory :
1 (N) Train scaler data
[PAW > nt/print 1
* Ntuple ID = 1 Entries = 1684 Train scaler data
* Var numb * Type * Packing * Range * Block * Name *
* 1 * I*4 * * * RUN * izrun
* 2 * R*4 * * * RUN * angl
* 3 * R*4 * * * RUN * helmh
* 4 * R*4 * * * RUN * ptarg
* 5 * I*4 * 9 * [-10,200] * RUN * itarg
* 6 * R*4 * * * RUN * xytarg(2)
* 1 * I*4 * * * ZUG * izug
* 2 * I*4 * * * ZUG * ifzug
* 3 * I*4 * * [0,4] * ZUG * nelem
* 4 * U*4 * 6 * [0,32] * ZUG * nscal
* 5 * I*4 * 5 * [-1,14] * ZUG * jfla(nelem)
* 6 * I*4 * 2 * [-1,1] * ZUG * jhel(nelem)
* 7 * I*4 * * * ZUG * jcnt(32,nelem)
* 8 * U*4 * 8 * [0,255] * ZUG * jadc(nelem)
* 9 * I*4 * * * ZUG * jtick(nelem)
* 10 * U*4 * 6 * [0,63] * ZUG * jdtickaf(nelem)
* 11 * U*4 * 6 * [0,63] * ZUG * jdtickal(nelem)
* Block * Entries * Unpacked * Packed * Packing Factor *
* RUN * 1684 * 28 * 26 * 1.077 *
* ZUG * 1684 * 624 * Var. * Variable *
* Total * --- * 652 * Var. * Variable *
* Blocks = 2 Variables = 17 Max. Columns = 163 *

Run 16008

Calorimeter + Aperature

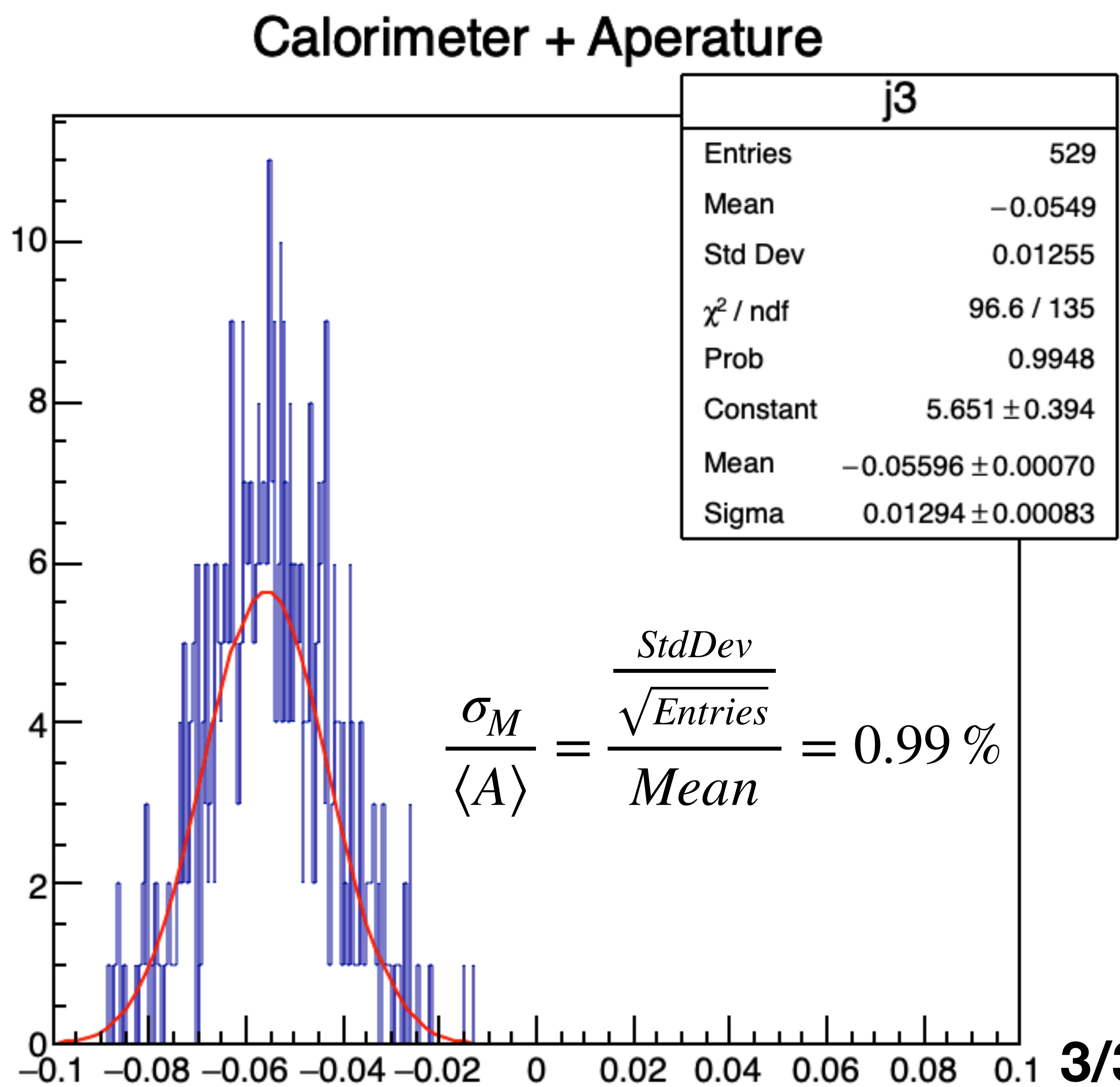


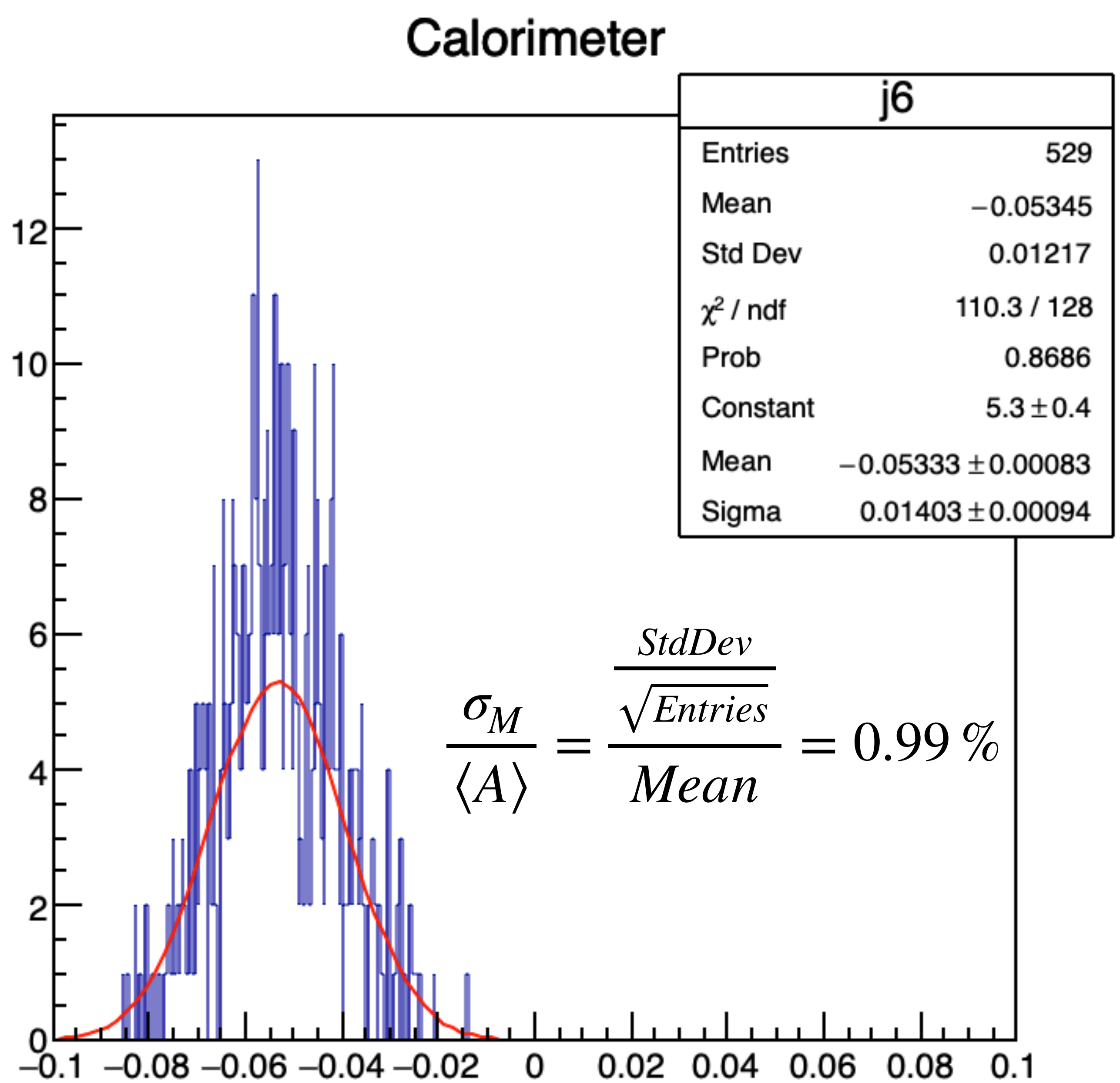
Calorimeter



2/29/16
8.8 GeV
Target 3 (12.5μm)
0.7 μA
4min 53 sec
59kHz

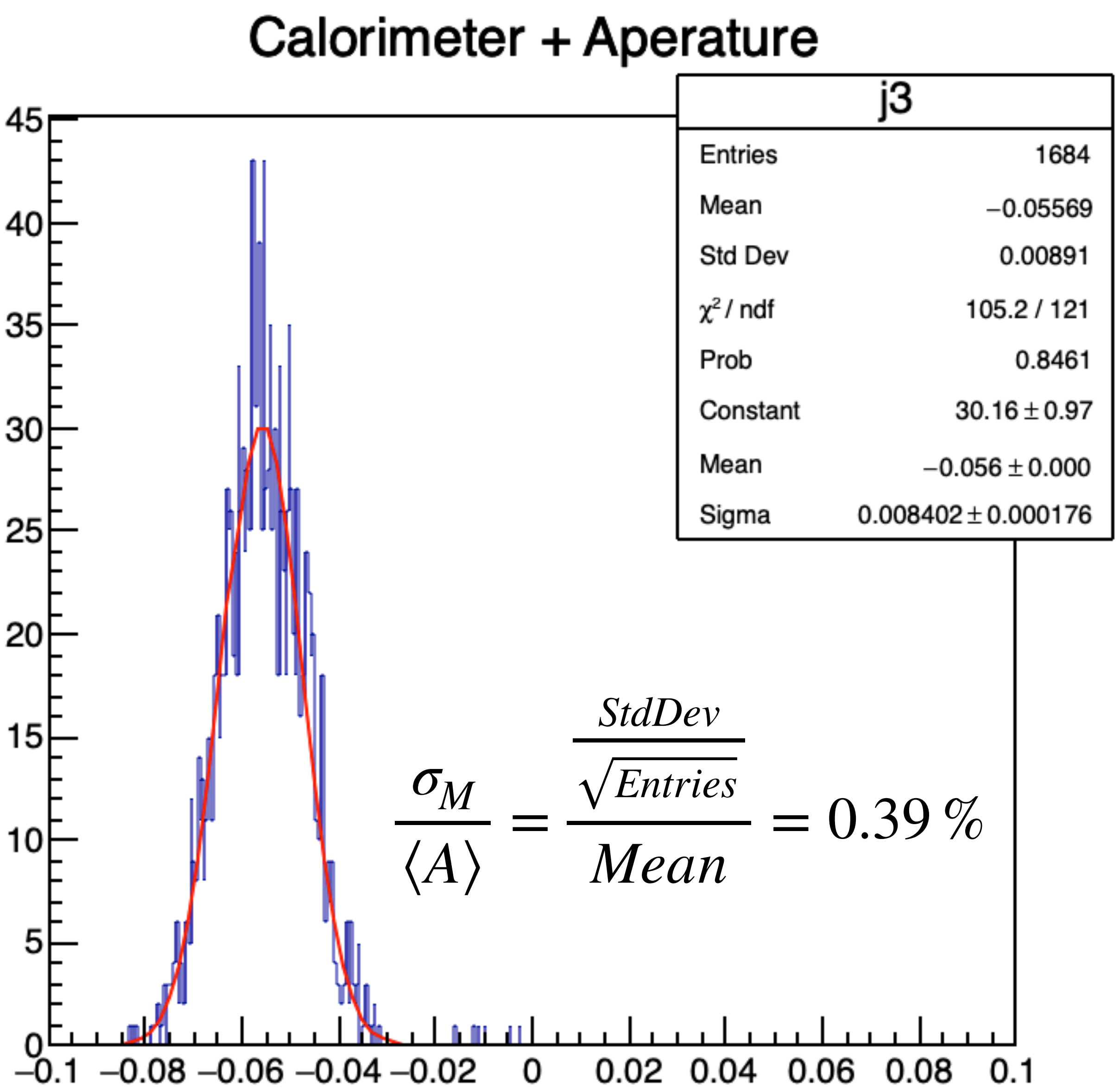
Run 16015

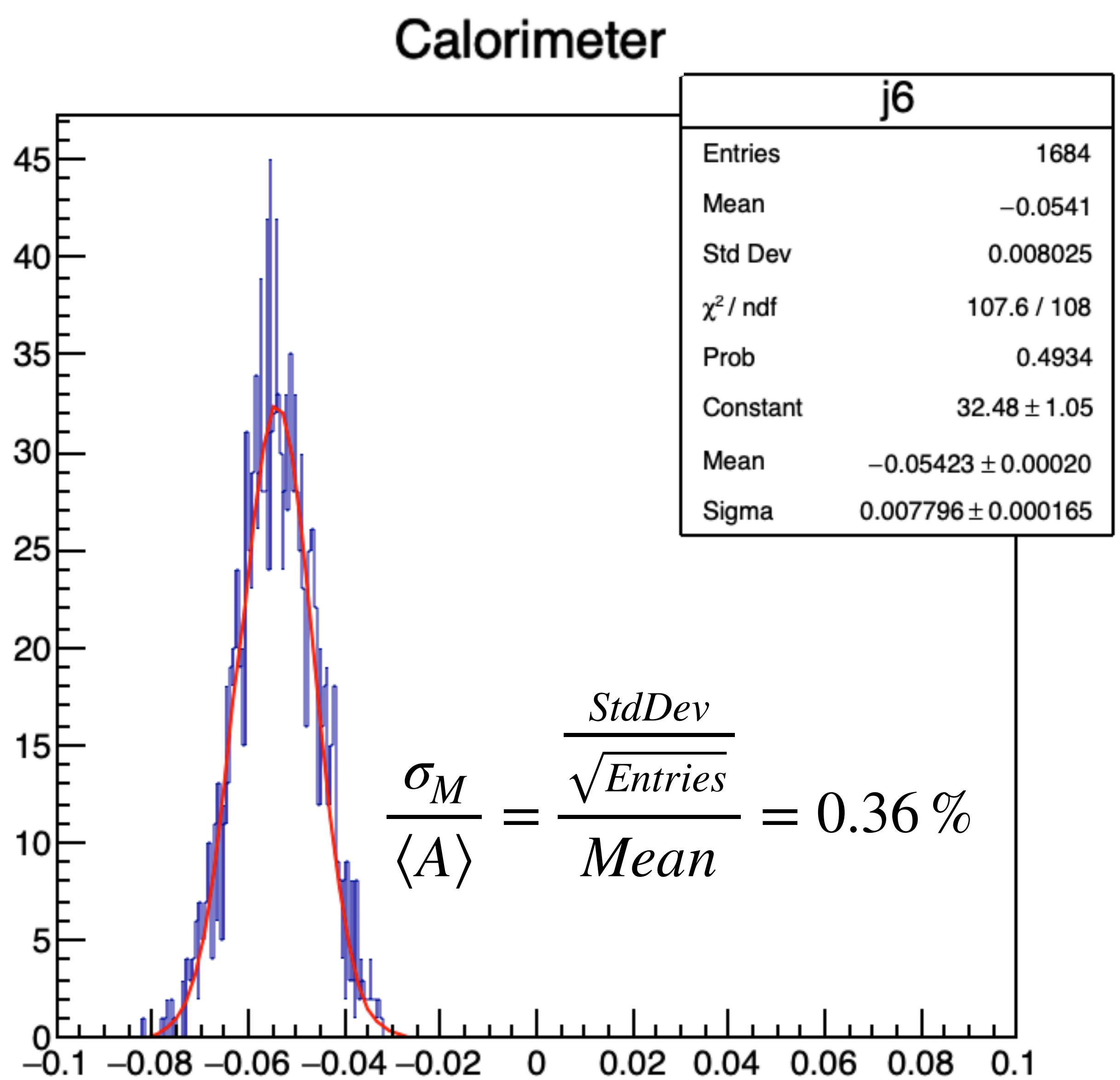




3/31/16
11.0 GeV
Target 3 (12.5µm)
1.0 µA
1min 18secs
53kHz

Run 16159





12/19/16
8.5 GeV
Target 3 (12.5μm)
1.5 μA
3min 55secs
94kHz

HALL C Møller

source	uncertainty	effect A
beam position x	0.5mm	0.15%
beam position y	0.5mm	0.03%
beam direction x	0.15mr	0.04%
beam direction y	0.15mr	0.04%
current Q1	2%	0.10%
current Q2	1%	0.07%
position Q2	1mm	0.02%
multiple scattering	10%	0.12%
Levchuk effect	10%	0.30%
position collimator	0.5mm	0.06%
target temperature	50%	0.05%
direction B-field	2°	0.06%
value B-field	5%	0.03%
spin polarization in Fe		0.25%
total		0.47%

able 1: Sensitivity of effective analyzing power to various sources of uncertainties.

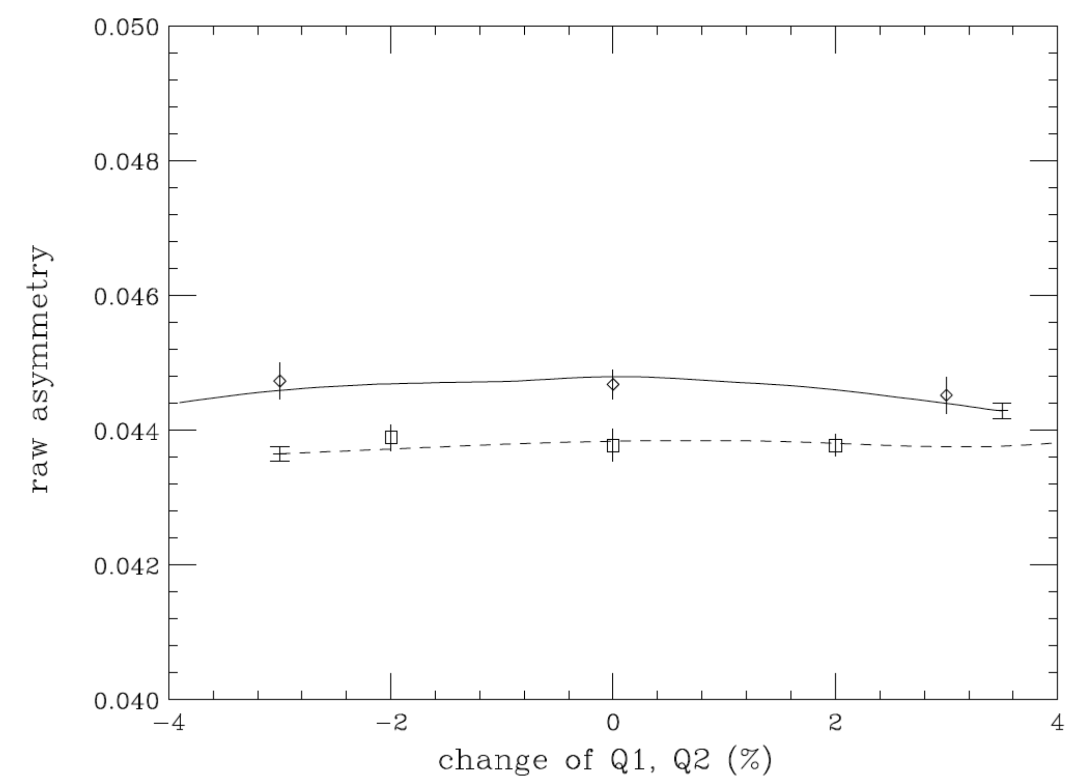


Figure 8: Change of the raw asymmetry with detuning of the quadrupoles Q1 (solid) and Q2 (dashed). The curves represent the MC simulation, the bar indicates the statistical uncertainty of the simulation.

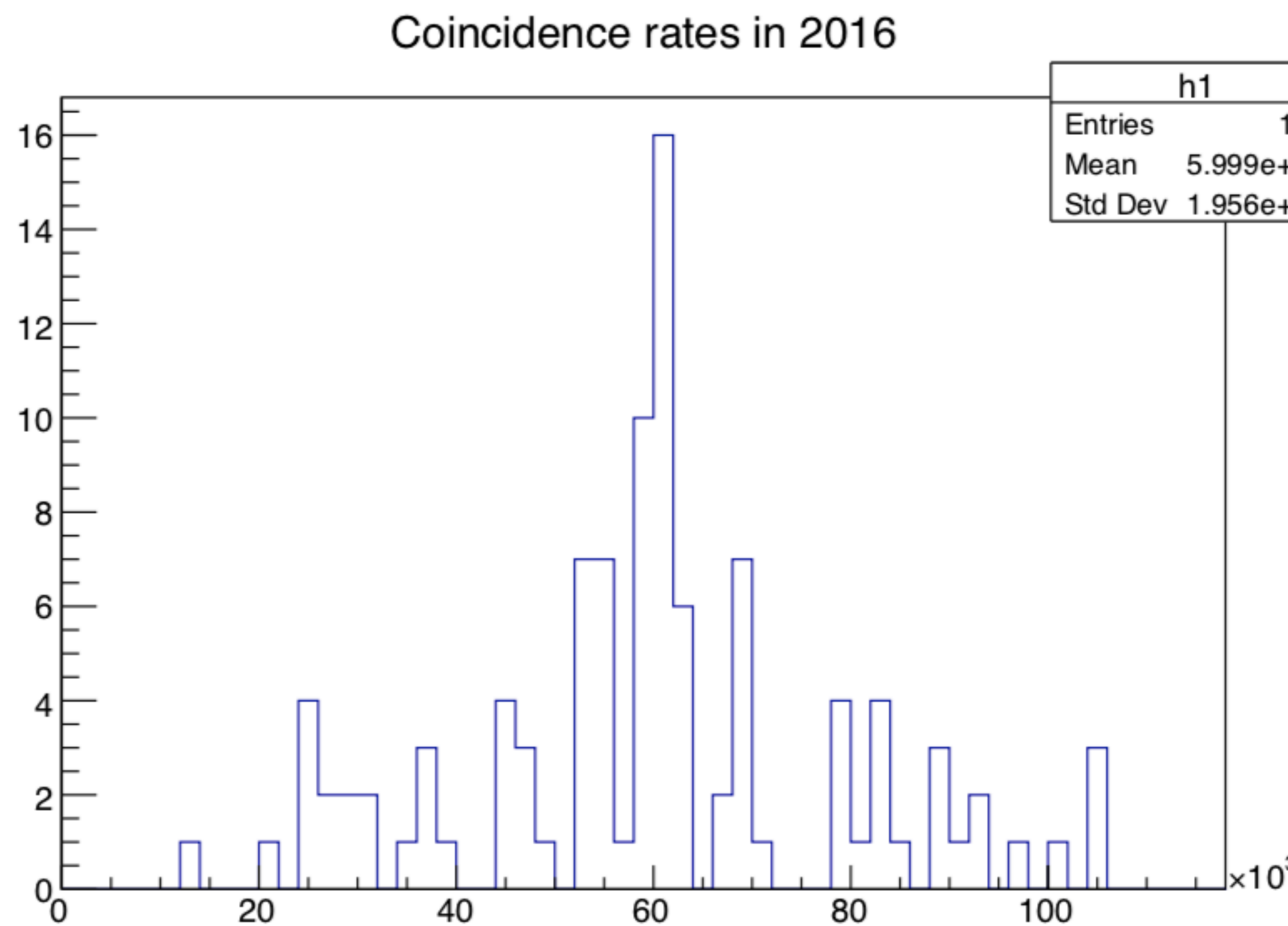
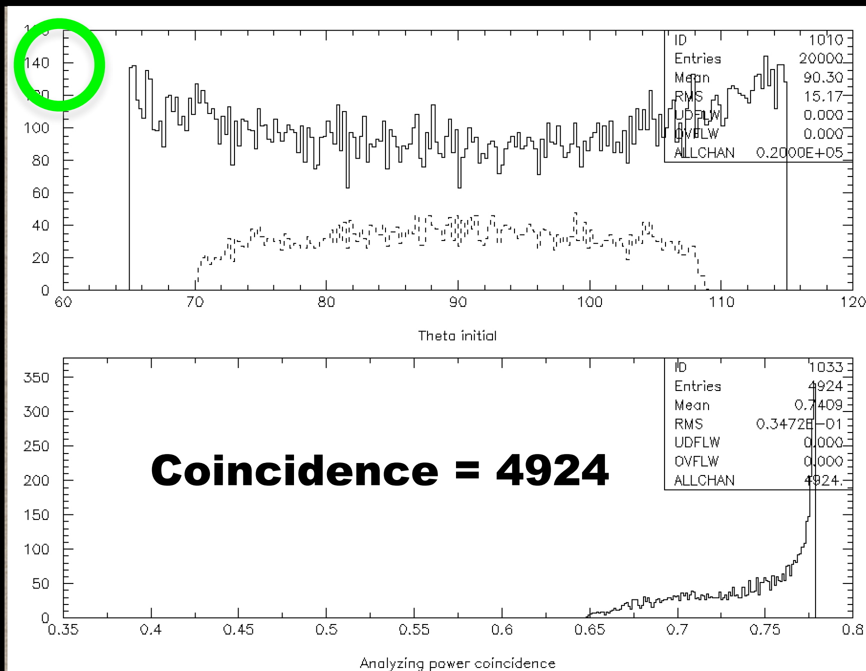


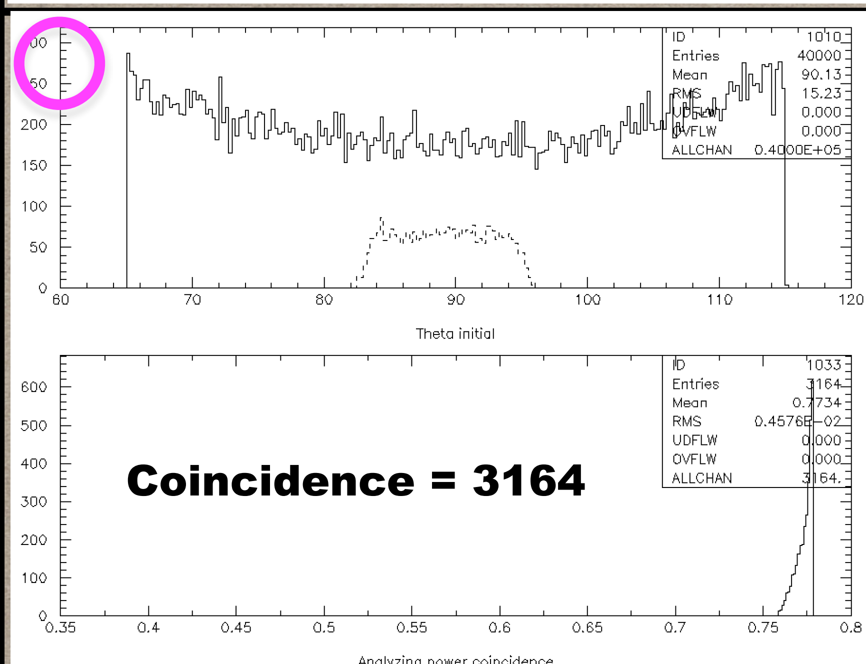
Figure 5: Coincidence rates for various runs in 2016 during DVCS

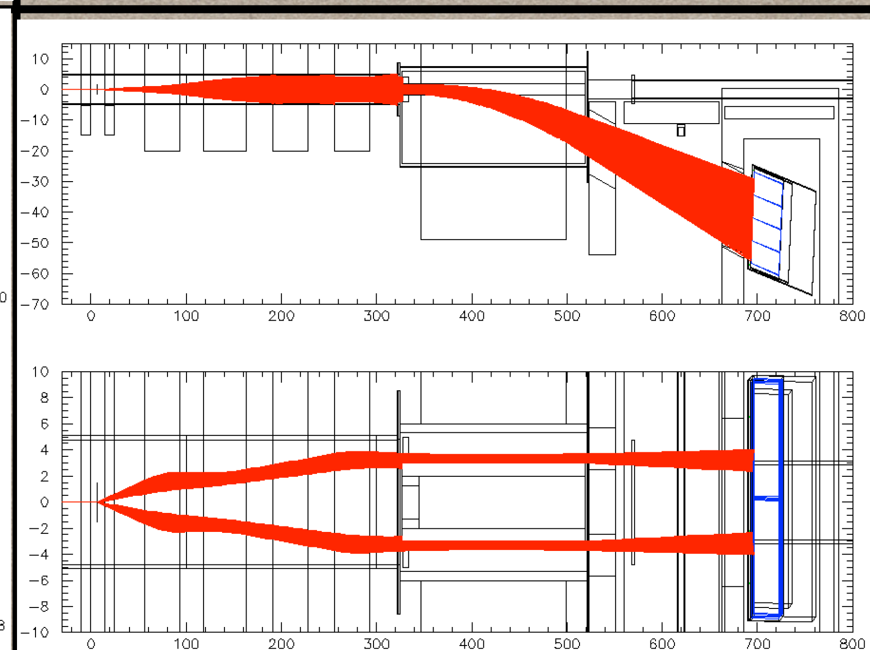
2.2 GEV OPTICS TUNE

Q1 = 5.0 kG



```
beammom 2.22 2.22001 0.0001
mollang 65. 115. -20. 20.
magf 1     5.
magf 2     -1.5
magf 3     0.
magf 4     1.6
magf 6     3.1
magf 5     0.6
```





```
beammom 2.22 2.22001 0.0001
mollang 65. 115. -20. 20.
magf 1     5.
magf 2     -1.1
magf 3     0.
magf 4     2.0
magf 6     3.7
magf 5     0.6
```

Calculating Levchuk Correction

Requires running simulation three times, each time scattering of a different shell (K,L,M(free e-)) in order to get # of coincidences.

$$Correction = \frac{r_1 - r_0}{r_0}$$

$$r_0 = \frac{a_p}{a_K + a_L + a_m} = \frac{2.216}{26}$$

$$r_1 = \frac{a_p * e_p}{a_K * e_K + a_L * e_L + a_M * e_p}$$

NOTE
Correction = 0
when $r_1 - r_0 = 0$
or when
$N_p = 1/5\ N_K + 4/5\ N_L$

$Coin_i$= Coincidence Events

N_i= Simulated Events

a_i=Fraction of e- in shell i

$$a_P = \frac{2.216}{26} \quad e_P = \frac{Coin_p}{N_p}$$

$$a_K = \frac{2}{26} \quad e_K = \frac{Coin_K}{N_K}$$

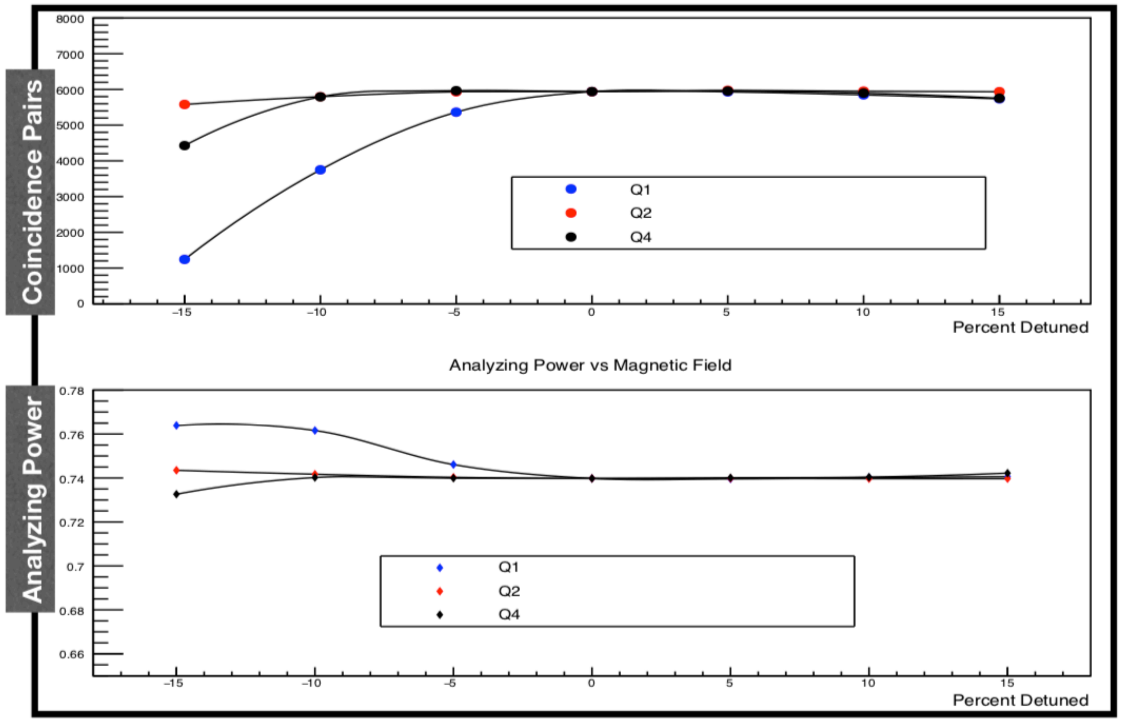
$$a_L = \frac{8}{26} \quad e_L = \frac{Coin_L}{N_L}$$

$$a_M = \frac{16}{26} \quad e_M = e_p$$

Current Geant3 solution for 2.2 GeV

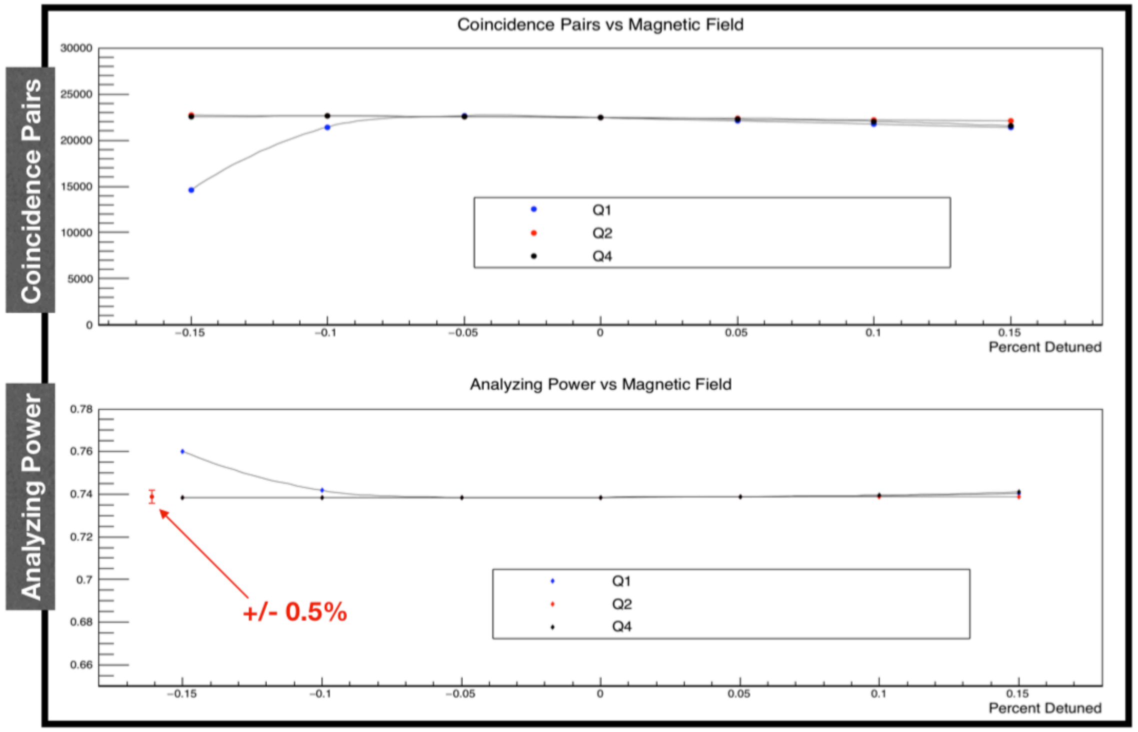
original solution 3

Q1=2.40 kG
Q2=0.45 kG
Q3=0.00 kG
Q4=1.05 kG

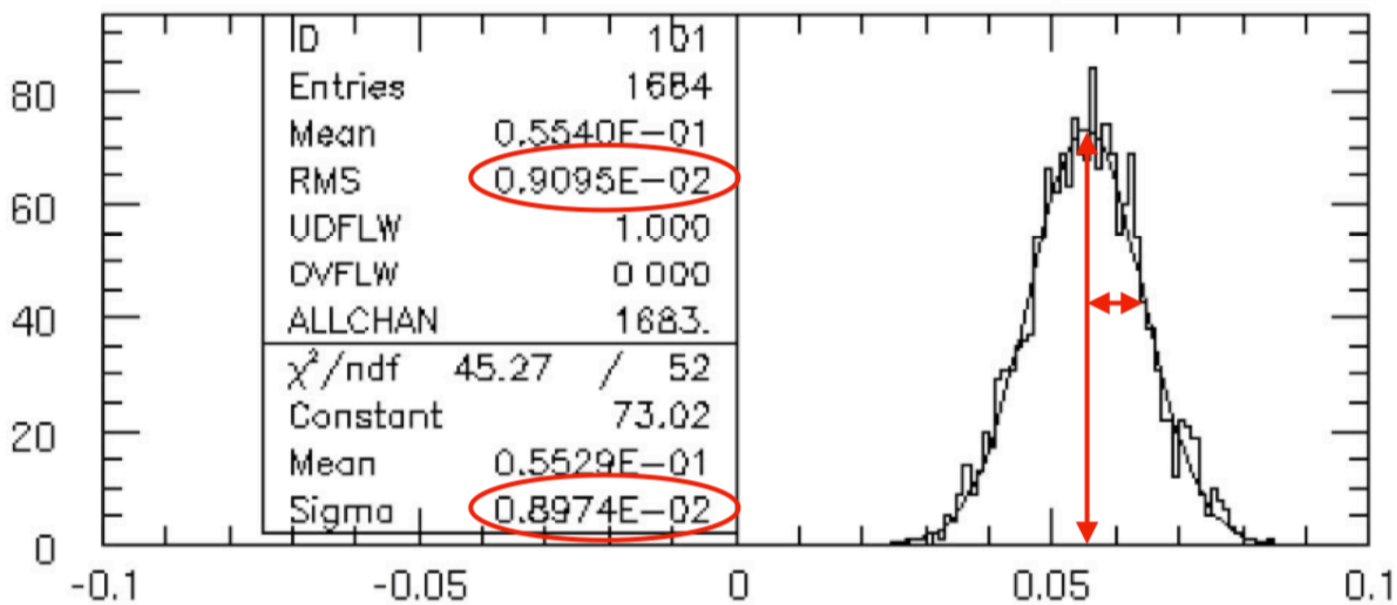


NEWEST SOLUTION

Q1=2.50 kG
Q2=0.50 kG
Q3=0.00 kG
Q4=1.00 kG



Data Analysis



Summary for run= 16159 Cycles: all= 6743 H+= 3355 H-= 3355

T.angle= 0.00 An.power= 0.7675 T.pol= 0.0804 Norm= 1. NormBCM= 1. Coils= 0.0 A gate= 0.0330 RunType= 0. Factor= 16.2143

no	Meaning	rate/cycle	rate/sec	raw asymmetry	corrected asymmetry	Polarization
1	Left arm	8317.1	252034.5 +/- 4365.5	0.0348 +/- 0.0124	0.0351 +/- 0.0001	0.5687 +/- 0.0022
2	Right arm	7457.2	225974.4 +/- 4268.4	0.0360 +/- 0.0135	0.0363 +/- 0.0001	0.5889 +/- 0.0023
3	Coincidence	3099.7	93929.9 +/- 2172.0	0.0552 +/- 0.0166	0.0554 +/- 0.0002	0.8975 +/- 0.0036
4	Coincidence accidentals	33.1	1004.2 +/- 178.0	0.0703 +/- 0.1252	0.0706 +/- 0.0021	0.0000 +/- 0.0000
5	BCM	1373.5	41620.6 +/- 527.4	-0.0003 +/- 0.0090	-0.0004 +/- 0.0002	0.0000 +/- 0.0000
6	Left arm accidentals / LED puls	3813.0	115544.3 +/- 2338.3	0.0538 +/- 0.0145	0.0541 +/- 0.0002	0.0000 +/- 0.0000
7	Timer	3352.3	101586.4 +/- 1239.8	0.0001 +/- 0.0086	0.0001 +/- 0.0086	0.0000 +/- 0.0000
8	Timer no helicity window in PLU	3352.3	101586.4 +/- 1239.8	0.0001 +/- 0.0086	-0.0000 +/- 0.0002	0.0000 +/- 0.0000
9	Left arm 2-nd	8315.1	251972.5 +/- 4369.4	0.0348 +/- 0.0125	0.0351 +/- 0.0001	0.5685 +/- 0.0022
10	Right arm 2-nd	7456.3	225949.4 +/- 4268.2	0.0360 +/- 0.0135	0.0363 +/- 0.0001	0.5888 +/- 0.0023
11	Coincidence 2-nd	3098.9	93906.9 +/- 2171.4	0.0552 +/- 0.0166	0.0554 +/- 0.0002	0.8976 +/- 0.0036
12	Coincidence accidentals 2-nd	32.2	975.4 +/- 175.1	0.0700 +/- 0.1267	0.0702 +/- 0.0021	0.0000 +/- 0.0000
13	Left LG delayed	9520.7	288504.6 +/- 4635.5	0.0341 +/- 0.0116	0.0343 +/- 0.0001	0.0000 +/- 0.0000
14	Right LG	8639.4	261798.6 +/- 4378.7	0.0347 +/- 0.0120	0.0350 +/- 0.0001	0.0000 +/- 0.0000
15	Sum LG	15381.6	466108.7 +/- 6855.0	0.0279 +/- 0.0106	0.0282 +/- 0.0001	0.0000 +/- 0.0000
16	Left App	26068.6	789958.9 +/- 19133.6	0.0193 +/- 0.0172	0.0196 +/- 0.0001	0.0000 +/- 0.0000
17	Right App	17572.8	532510.2 +/- 9748.9	0.0165 +/- 0.0130	0.0168 +/- 0.0001	0.0000 +/- 0.0000

Factor=16.2143
Asymmetry(Calorimeter+Aperture)=0.0553954
Asymmetry (Calorimeter only)=0.0539786
Polarization (Calorimeter)=-87.5225
Polarization(Calorimeter+Aperture)=-89.8198+/-0.360724

For one asymmetry measurement

$$\delta A \approx \frac{1}{\sqrt{N_+ + N_-}}.$$

$$\delta A = \frac{1}{4(3099.7) - 4(33.1)} = 0.009029$$

For many asymmetry measurements (One Run)

$$\sigma_M = \frac{\delta A}{\sqrt{N}}$$

$$A = \bar{A} \pm \sigma_M$$

$$A = 0.05540 \pm 0.00022$$

$$\frac{\sigma_M}{A} = \frac{0.00022}{0.05540} = 0.397\,\%$$

Hall A high field iron target: lessons learned

Used for PREX ($\sim$1 GeV) and DVCS ($\sim$5 GeV)

- Coils - strong beam steering
  - No remote motion/steering of the magnet
  - Elaborate attempts to align the magnet with the help of the survey group - little success
  - Can the coils move inside the cryo-vessel?
- Optimal Q1 current is about 15% off the mark at 1 GeV
  No explanation so far $\Rightarrow$ systematic error on analyzing power
- Variation between targets $\sim$0.5-1.0% - material or the field angle? (3° $\Rightarrow$ 1% at 3 T, 0.3% at 4 T)
- No full saturation visible ($\sim$1% level) at 3-4 T $\Leftarrow$ Levchuk effect depends on the field

The goal for the systematic error

Variable	Error		
	OLD	Present	PREX goal
Target polarization	3.5%	2.0%	0.5%
Target angle	0.5%	0.5%	0.0%
Analyzing power	0.3%	0.3%	0.3%
Levchuk effect	0.2%	0.2%	0.2%
Dead time	0.3%	0.3%	0.3%
Others	-	-	0.3%
Total	3.6%	2.1%	$\sim$1.0%

Parameter	$< A_{zz} >$	$\cos\Theta_{targ}$	P_{targ}	**Total :**
Error	0.25 %	≤ 1 %	≤ 3 %	$\sim 3\%$

Systematic error

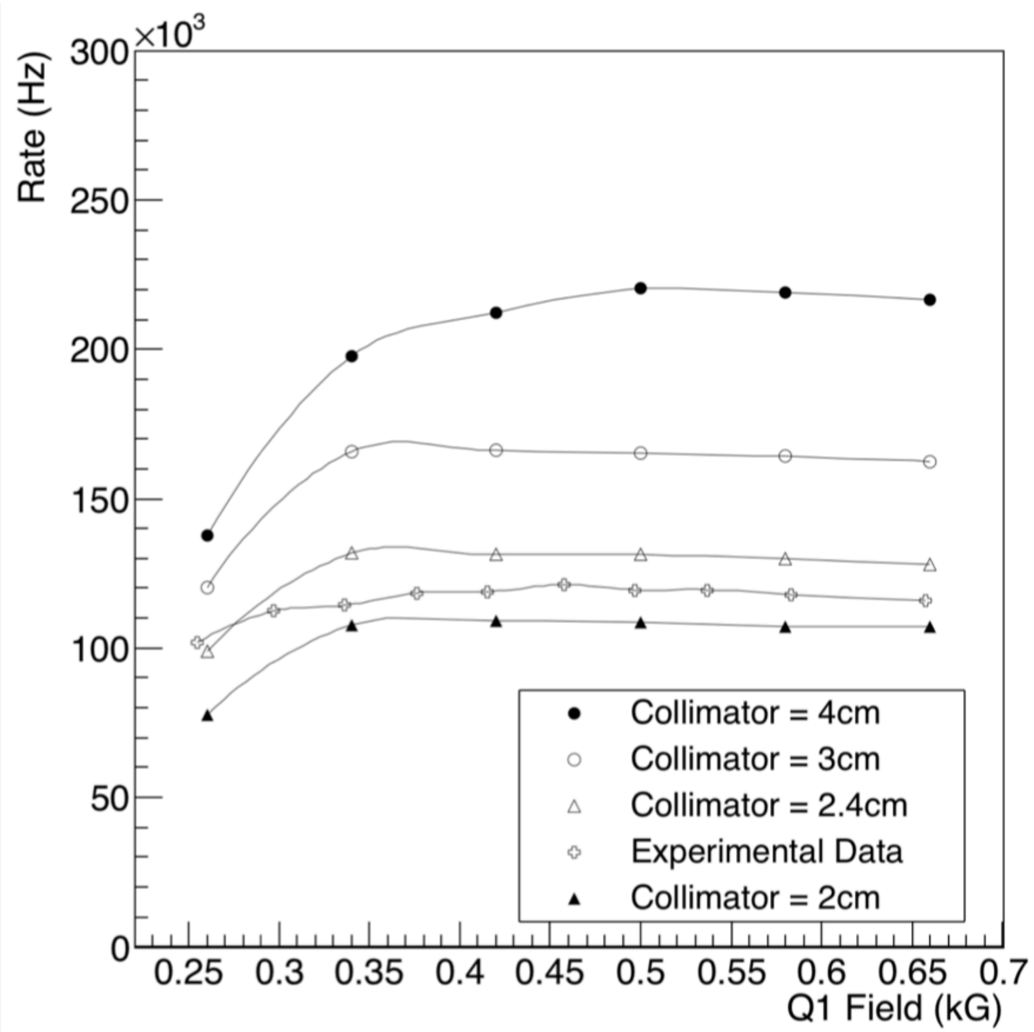
Variable	Error	
	OLD	NEW
Target polarization	3.5%	2.0%
Target angle	0.5%	0.5%
Analyzing power	0.3%	0.3%
Levchuk effect	0.2%	0.2%
Dead time	0.3%	0.3%
Total	3.6%	2.1%

Møller Polarimeter Systematic Error (2005-2009)

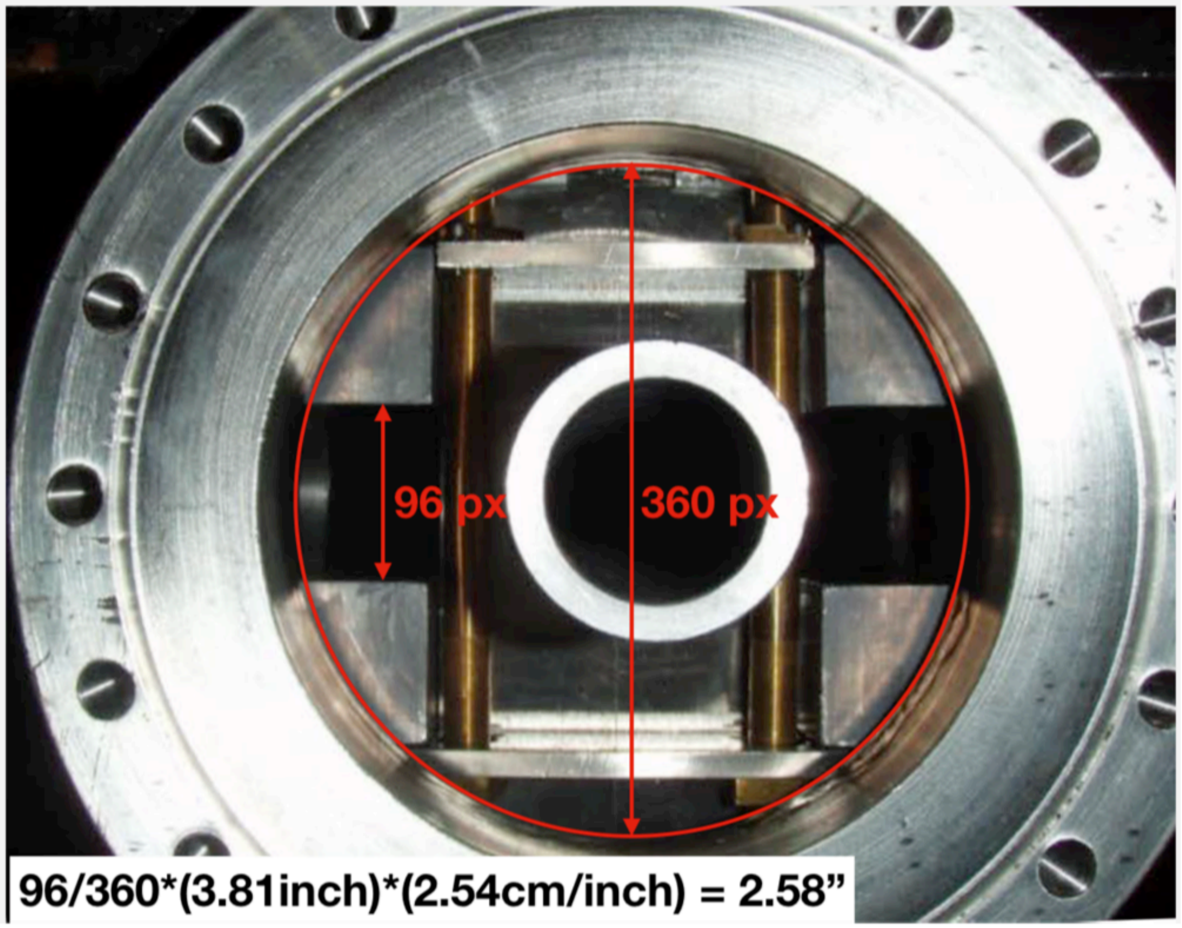
Variable	*Error, %*
Target	*1.5*
Analyzing power	*0.3*
Levchuk-effect	*0.2*
Dead time	*0.3*
Background	*0.3*
Others	*0.5*
Total	*1.7*

Systematic Error for PREX

Variable	PREX(old DAQ)
Iron Foil Polarization	0.25%
Targets Discrepancy	0.5%
Target Saturation	0.3%
Analyzing power	0.3%
Levchuk effect	0.5%
Target temperature	0.02%
Dead time	0.3%
Background	0.3%
Others	0.5%
Total	1.1%



Rate (Hz)
×10³
300
250
200
150
100
50
0
0.25 0.3 0.35 0.4 0.45 0.5 0.55 0.6 0.65 0.7
Q1 Field (kG)
Collimator = 4cm
Collimator = 3cm
Collimator = 2.4cm
Experimental Data
Collimator = 2cm



96 px
360 px
96/360*(3.81inch)*(2.54cm/inch) = 2.58”

INTRODUCTION: THE SET-UP

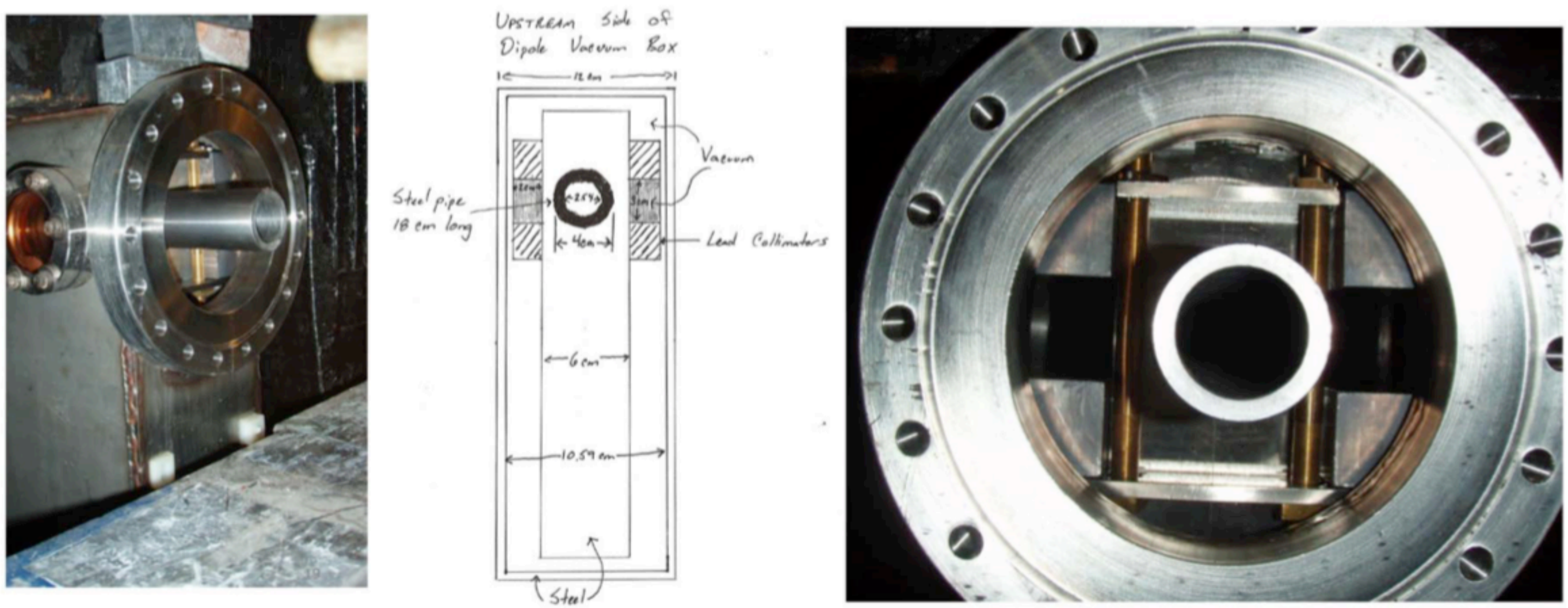


Figure 4.24: Dipole entrance and collimators

INTRODUCTION: THE SET-UP

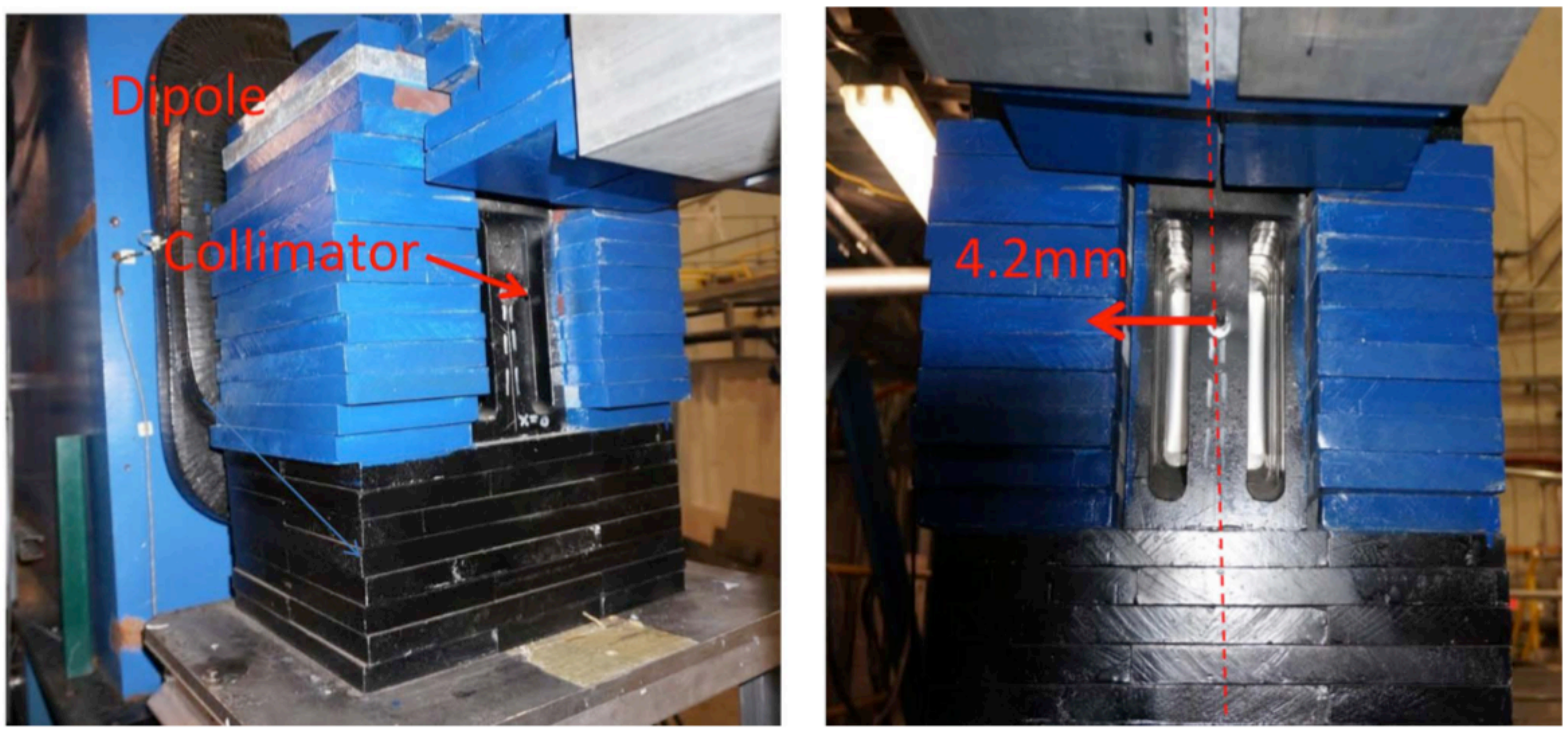
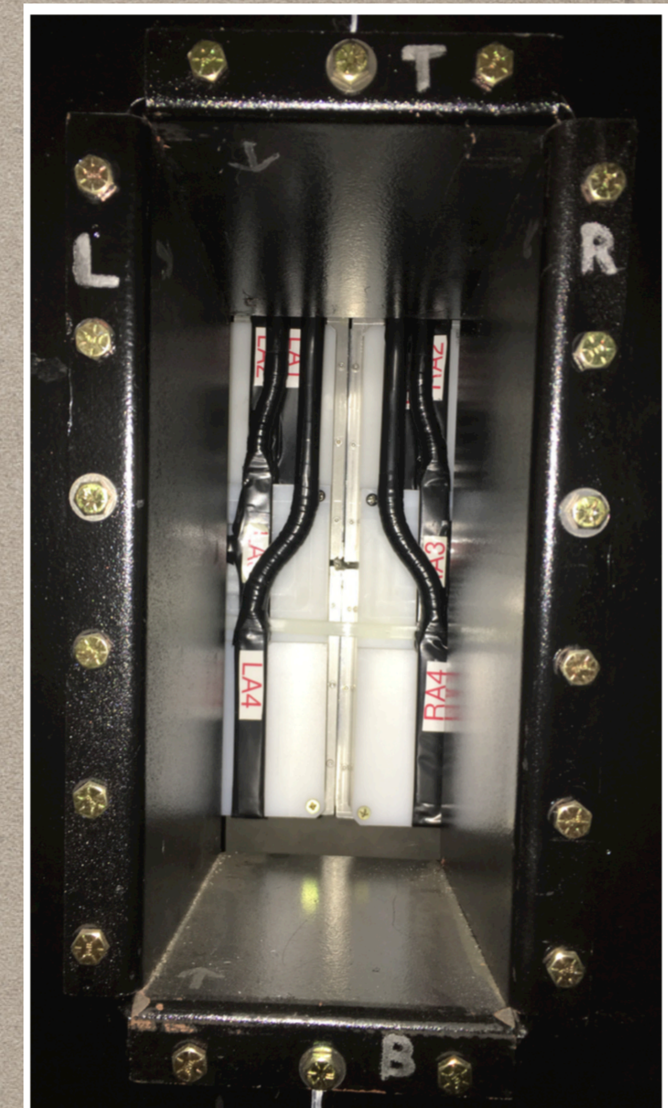


Figure 4.25: Lead shielding at dipole exit



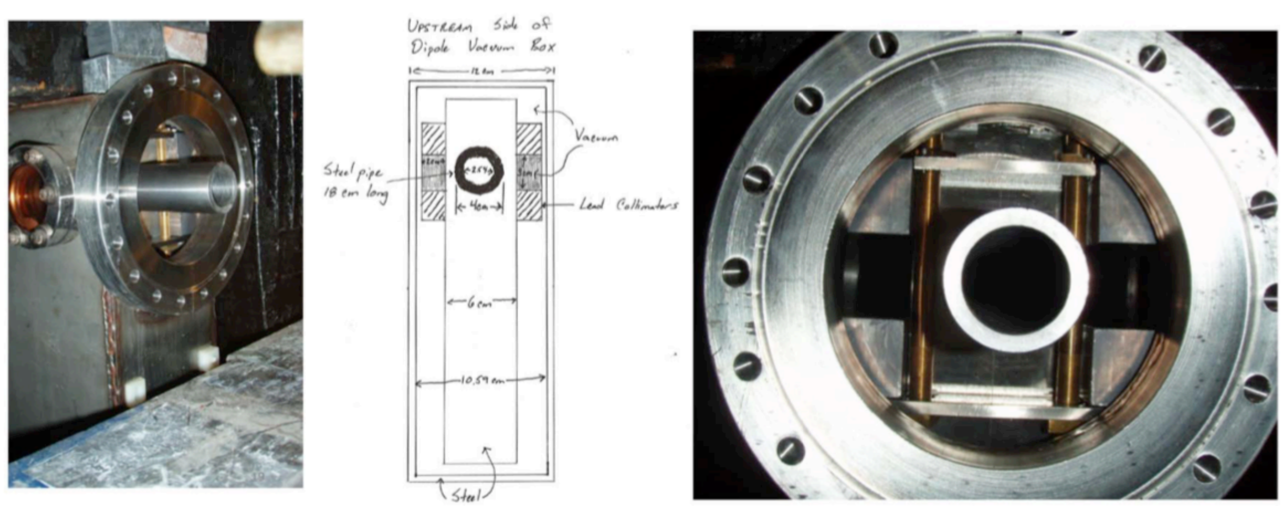


Figure 4.24: Dipole entrance and collimators