PVDIS (6GeV) Data Analysis Report (Detailed)

Diancheng Wang (UVa)
Jan. 6th, 2012

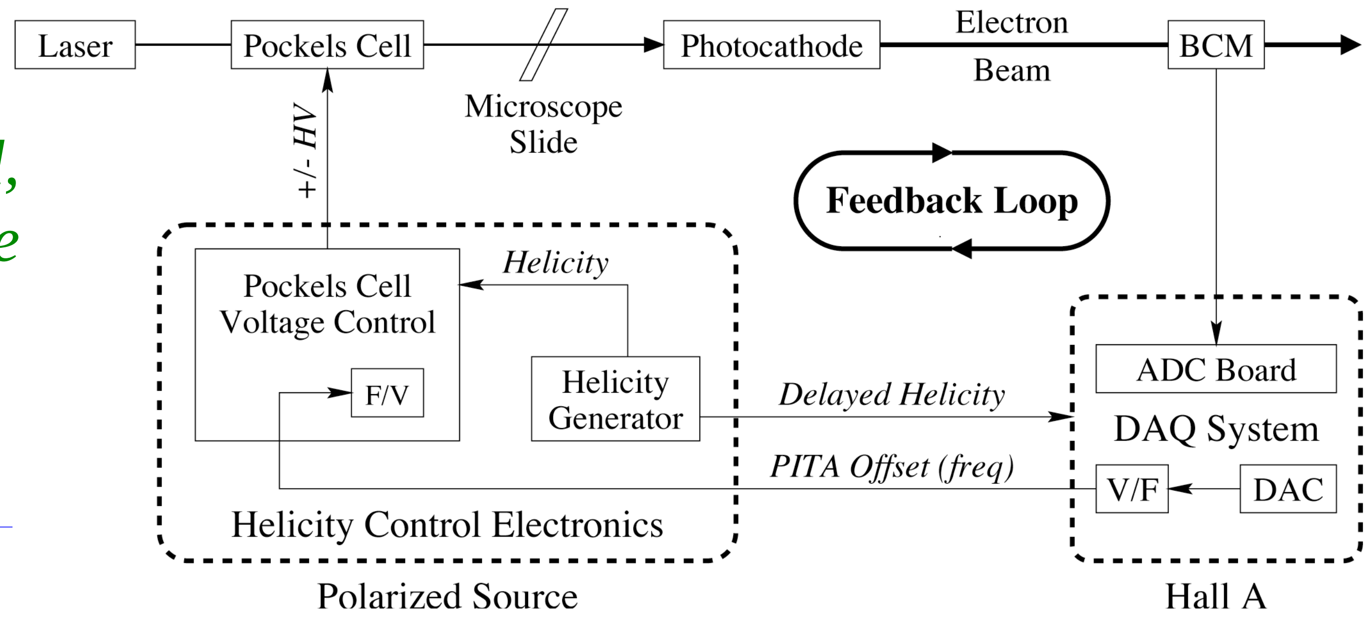
- Electron/Pion DIS Asymmetry Analysis
- Beam Polarization (Compton/Moller)
- Deadtime Correction
- Radiation Correction

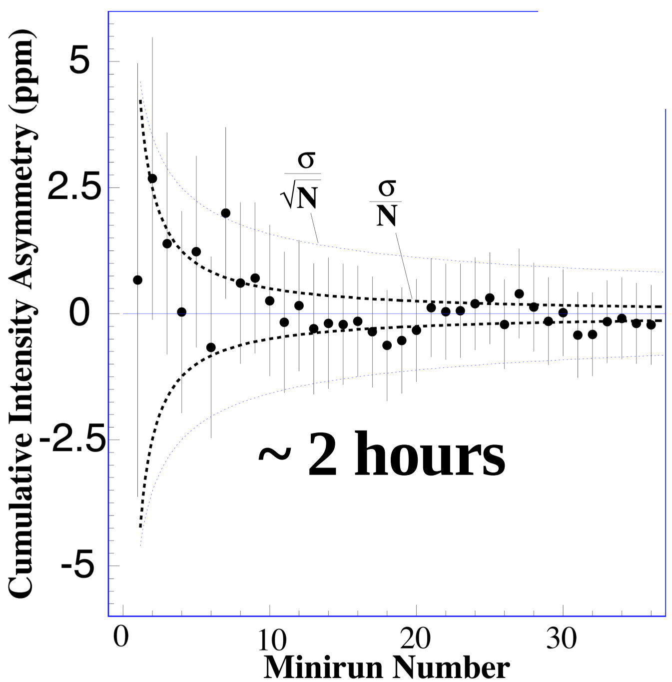
Asymmetry Analysis:

- Charge Asymmetry: BCM calibration, Intensity Feedback....
- Beam Modulation: Dithering/Regression analysis
- Fine-tuning cuts: low-beam, beam-burp.....
- Electron/Pion DIS, Electron Resonance, Positron, Transverse......

Intensity Feedback

With passive measures optimized, Feedback zeroes the helicity-correlated effects even further





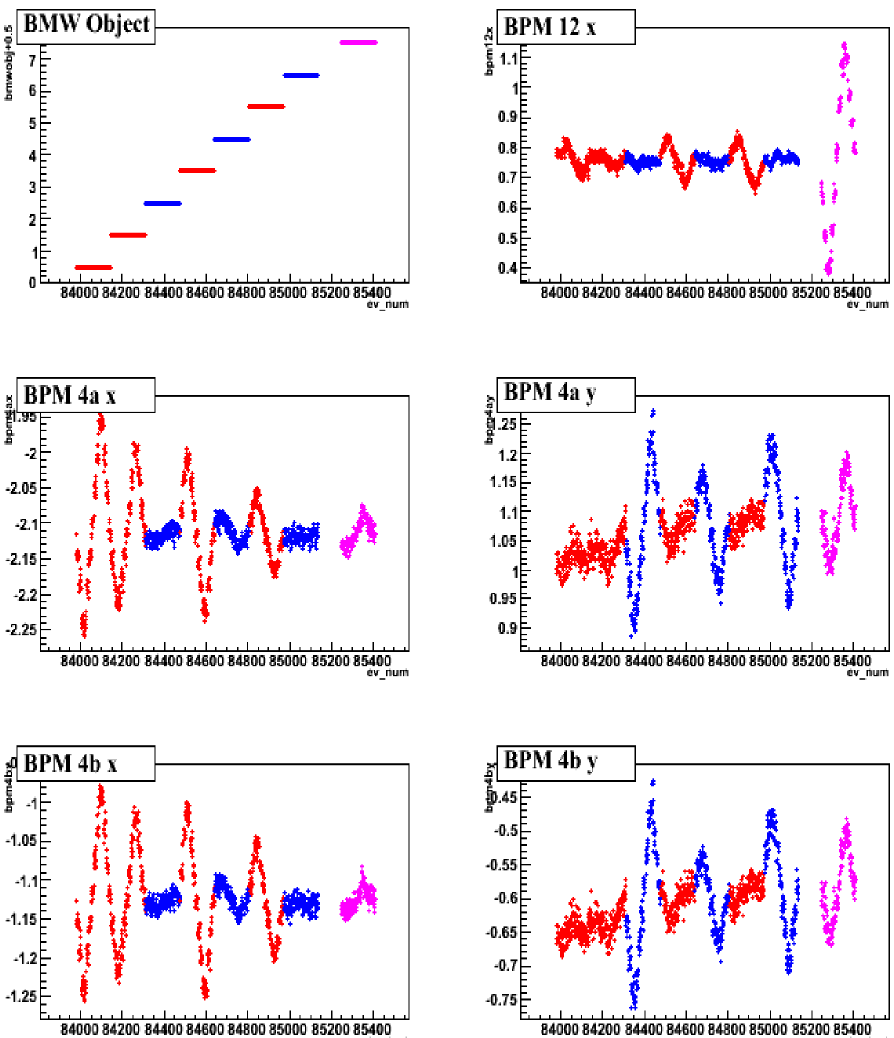
Low jitter and high accuracy allows sub-ppm Cumulative charge asymmetry in ~ 1 hour

Beam Modulation

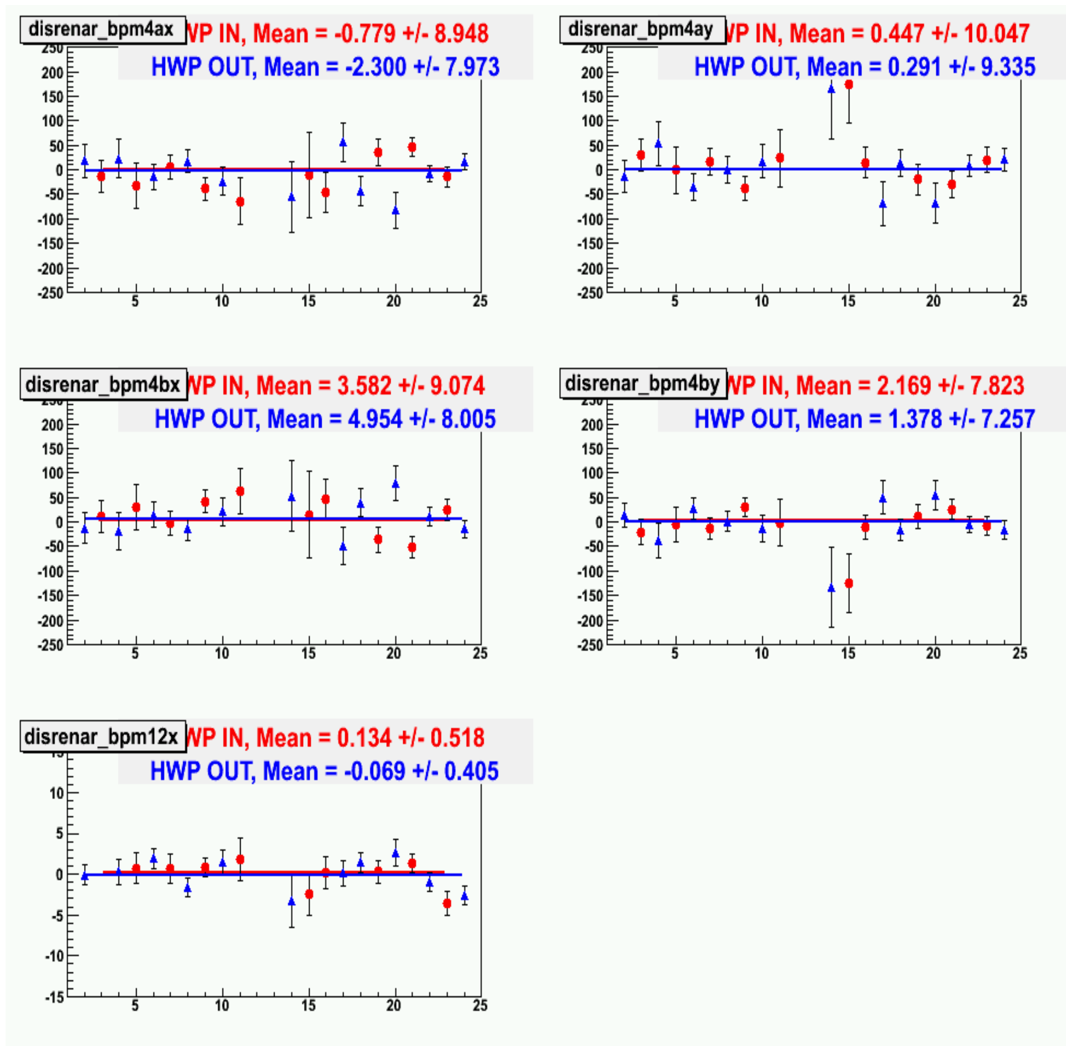
$$A_{mes} = A_{raw} - A_{beam} - \boxed{\sum \beta_i \Delta x_i}$$

Two independent methods:

- Dithering: intentionally vary the beam parameters
- Regression: use the natural motion of the beam

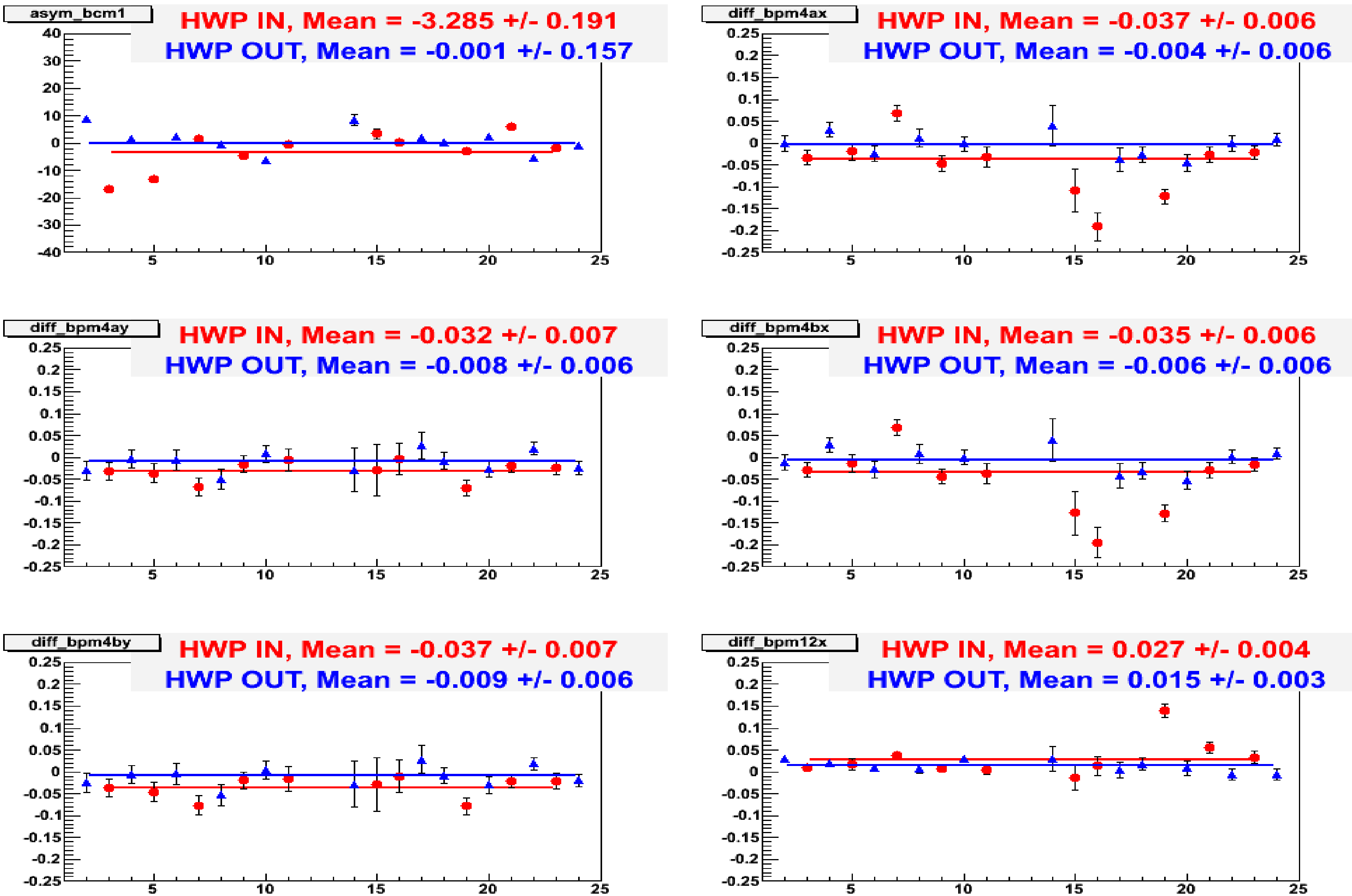


Dithering plots

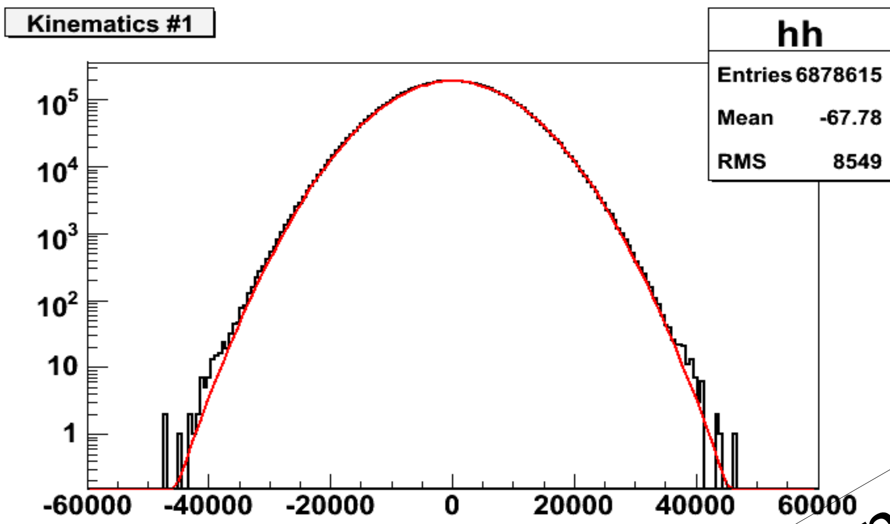


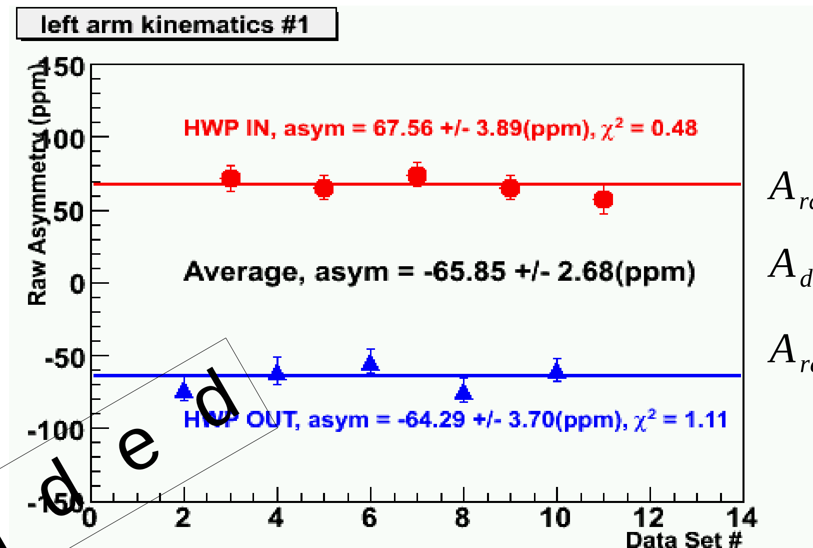
Dithering slopes (β_i ' s) history:

Beam Asymmetries



Raw Electron Asymmetries

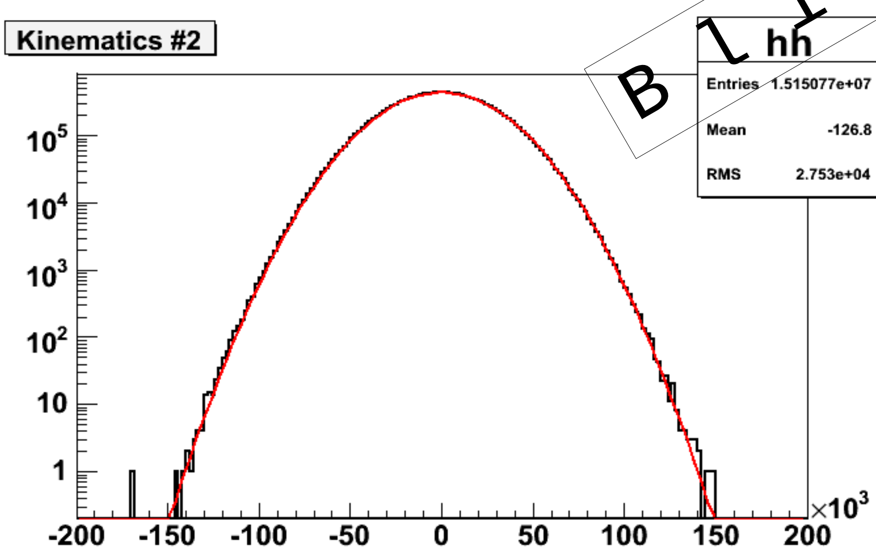


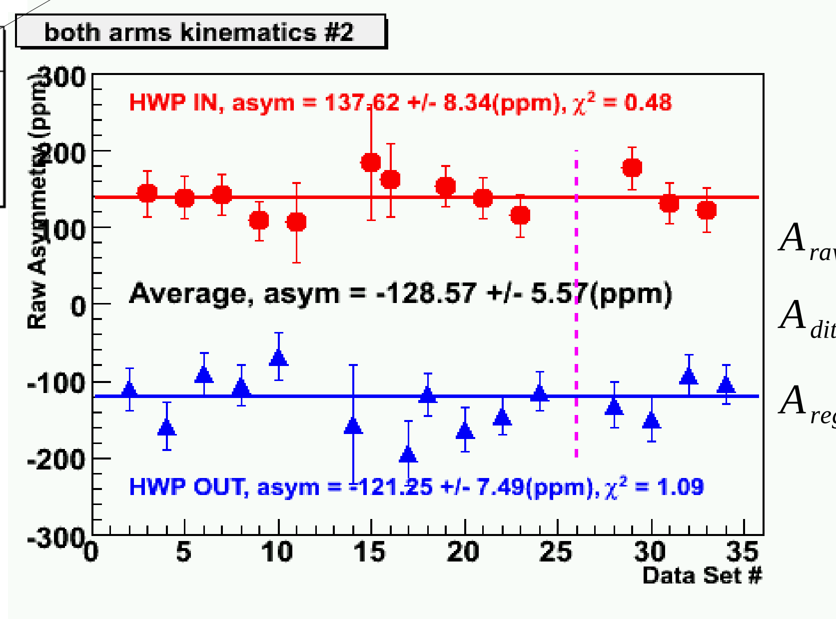


$A_{raw} = -65.85\text{ppm}$

$A_{dit} = -65.85\text{ppm}$

$A_{reg} = -65.93\text{ppm}$





$A_{raw} = -128.57\text{ppm}$

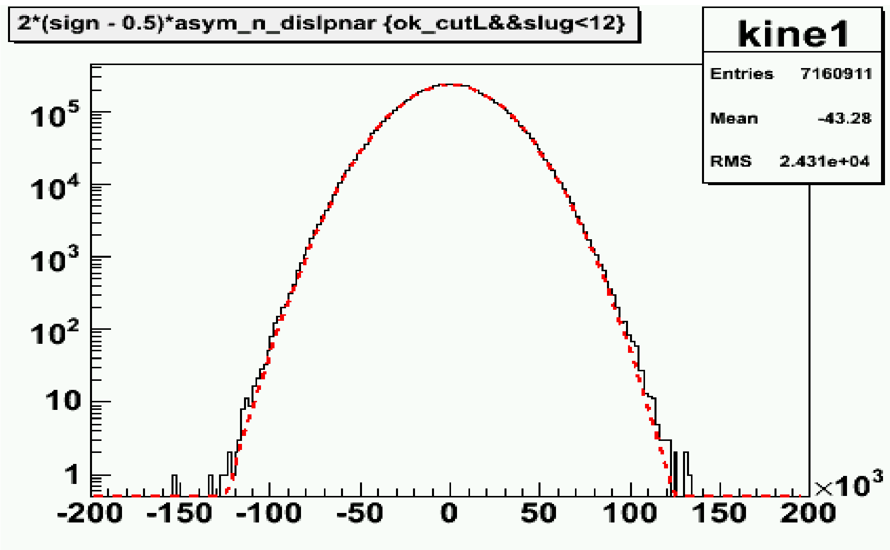
$A_{dit} = -128.52\text{ppm}$

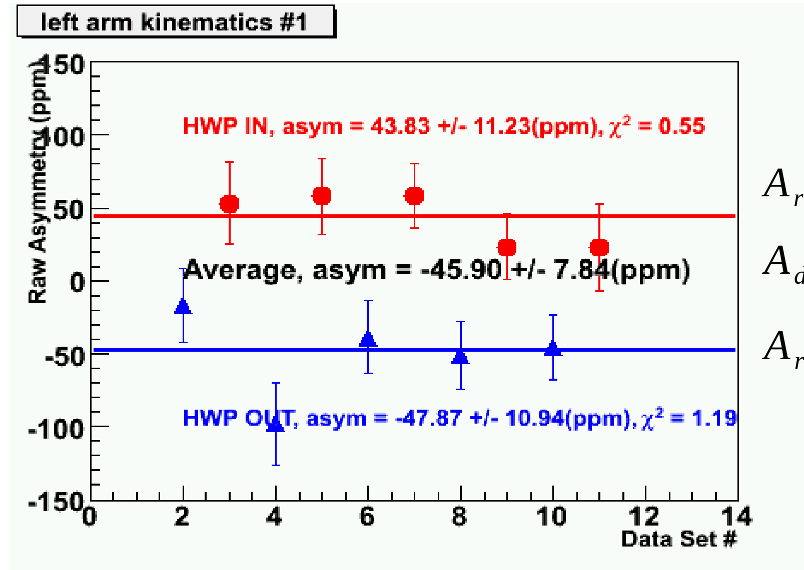
$A_{reg} = -128.87\text{ppm}$

Blinded

Doing two independent analyses, difference between the two is ~0.3ppm

Raw Pion Asymmetries

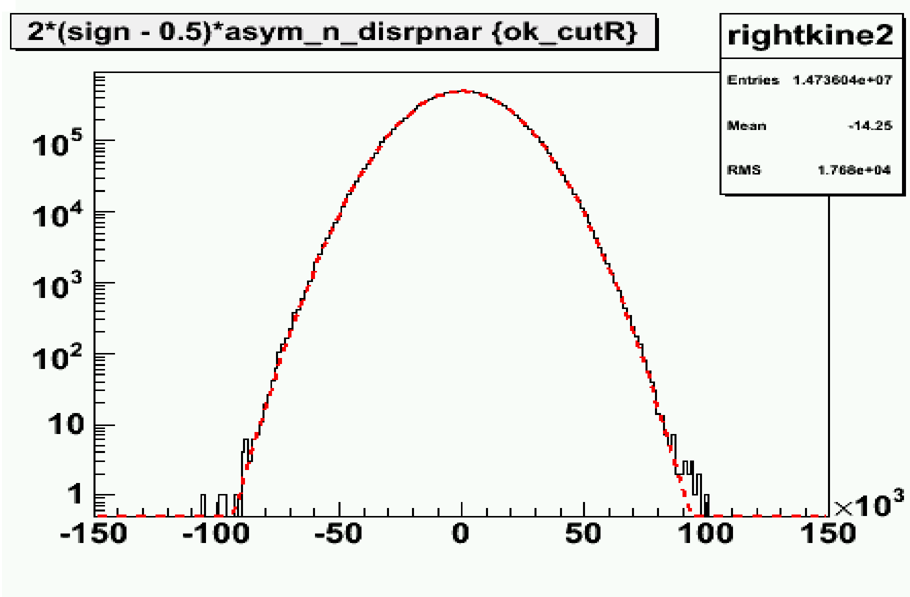


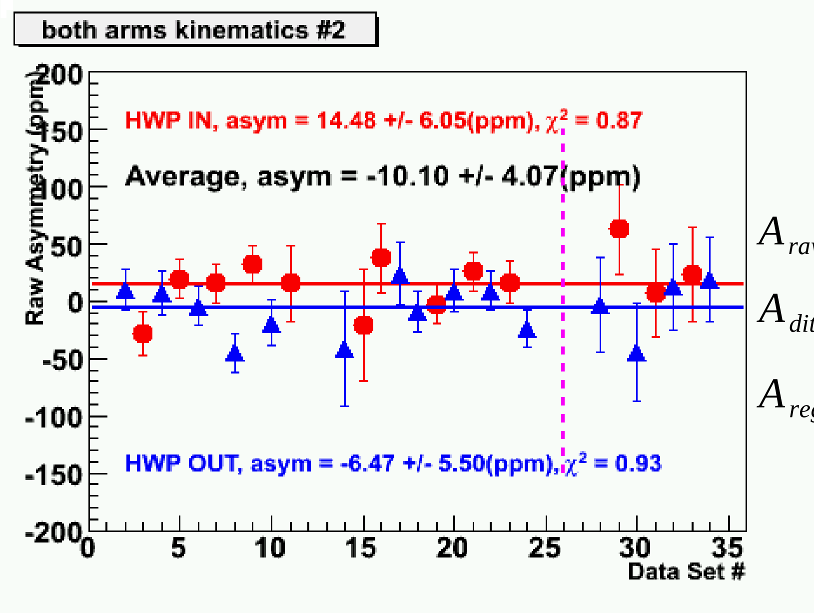


$$A_{raw} = -45.90\text{ppm}$$

$$A_{dit} = -45.88\text{ppm}$$

$$A_{reg} = -45.56\text{ppm}$$





$$A_{raw} = -10.10\text{ppm}$$

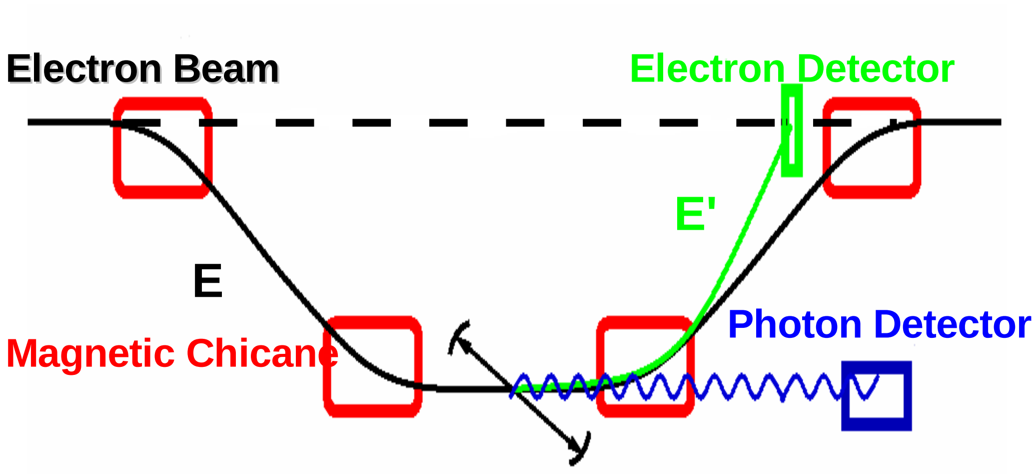
$$A_{dit} = -10.11\text{ppm}$$

$$A_{reg} = -10.23\text{ppm}$$

Doing two independent analyses, difference between the two is ~0.3ppm

Beam Polarization / Compton

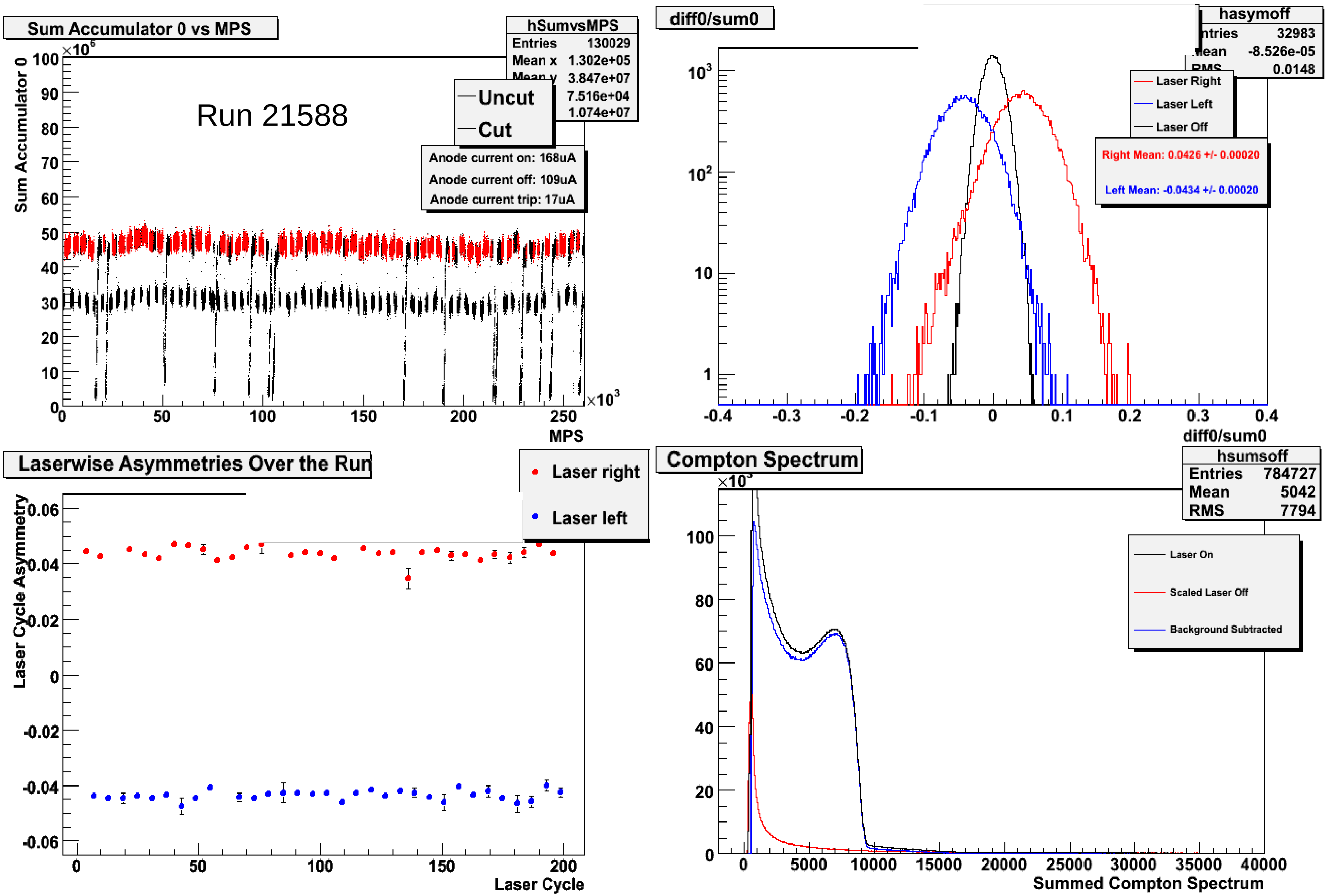
$$A' = A_{measure} / Polarization$$



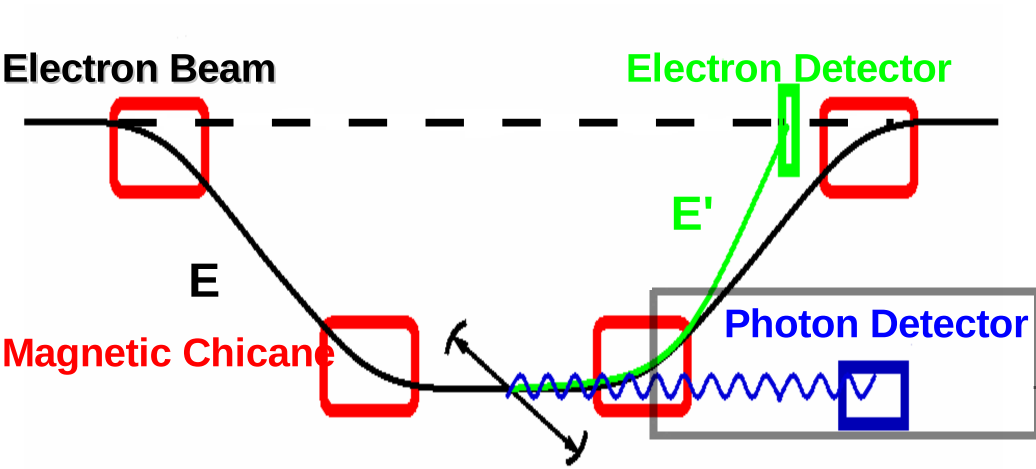
$$A_{\exp} = P_{\gamma} \times P_{e} \times A_{th}$$

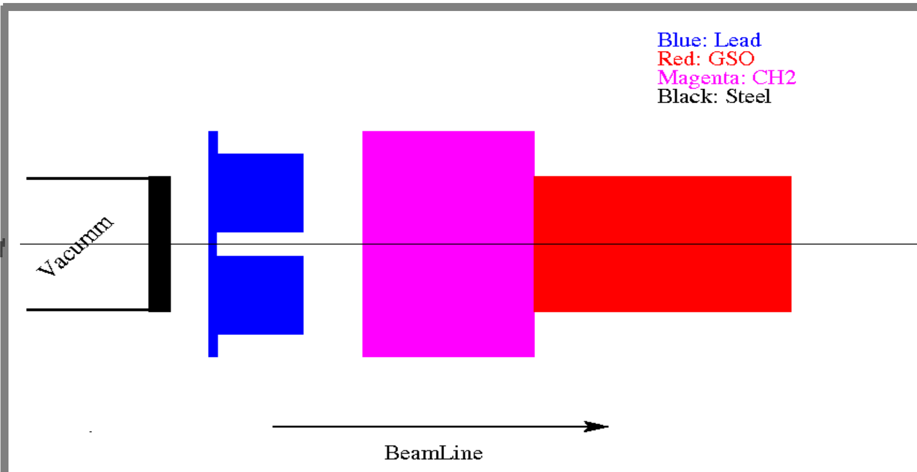
- Analyzing power (Ath) calculated using GEANT4 simulation, and is the leading uncertainty.
- Asymmetry measured using photon detector with integrating FADC DAQ.
  - Stands alone, no coincidence calibration needed.
  - Doesn't care about pile-up, deadtime, etc...

Integrating FADC Analysis, online plots



Analyzing Power





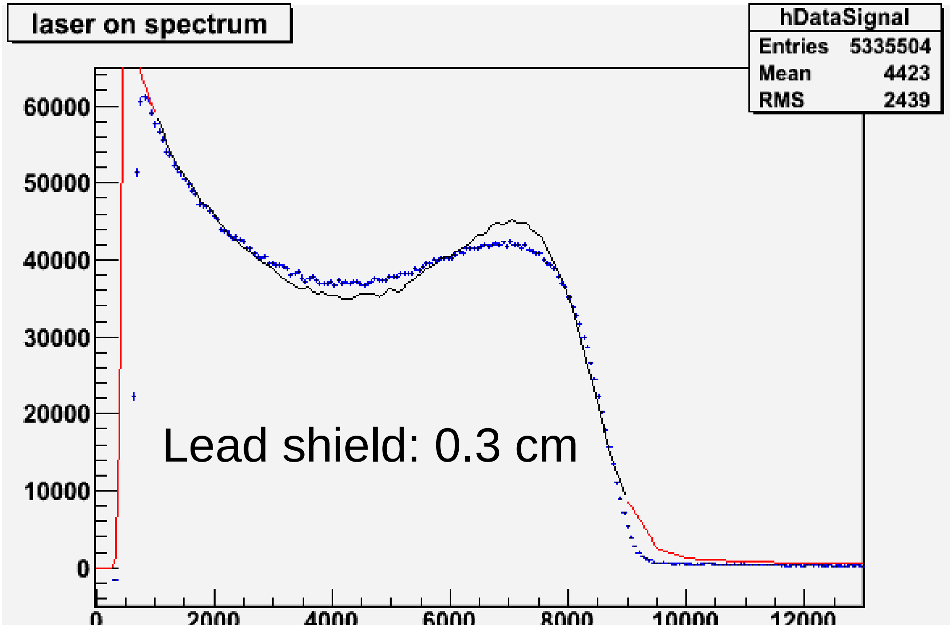
Vacuum End Cap(steel): 0.05cm
Lead shielding thickness: 0.3 cm
Collimator: inner radius 0.5cm
outer radius 4.0 cm, length 5.0 cm
CH2: radius 5.0 cm, length 10.2 cm
GSO: radius 3.0 cm, length 15.0 cm

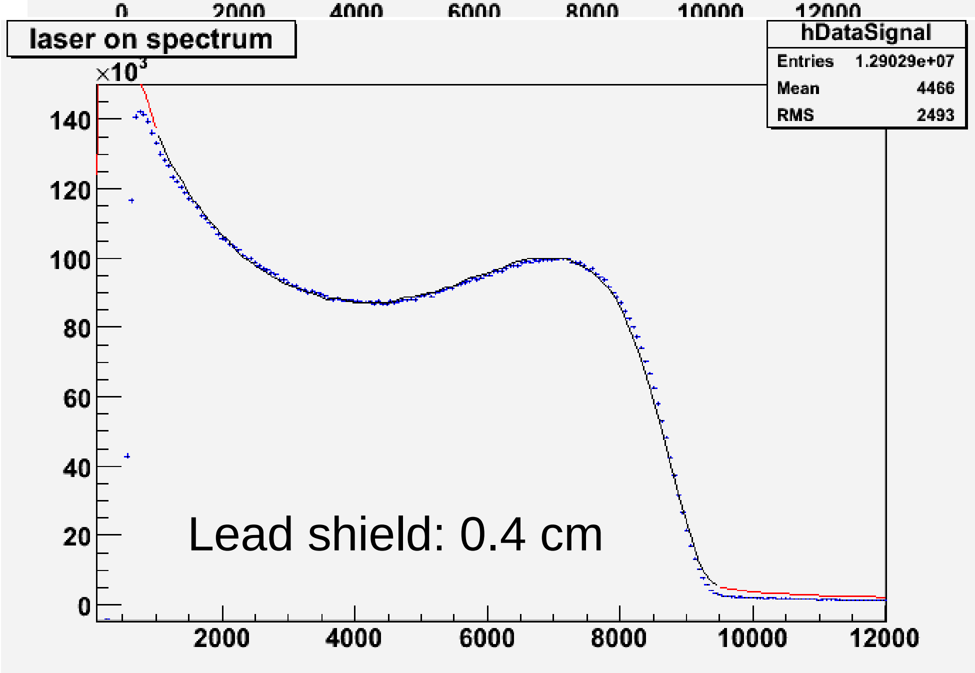
GEANT4 MC to calculate A_{th}

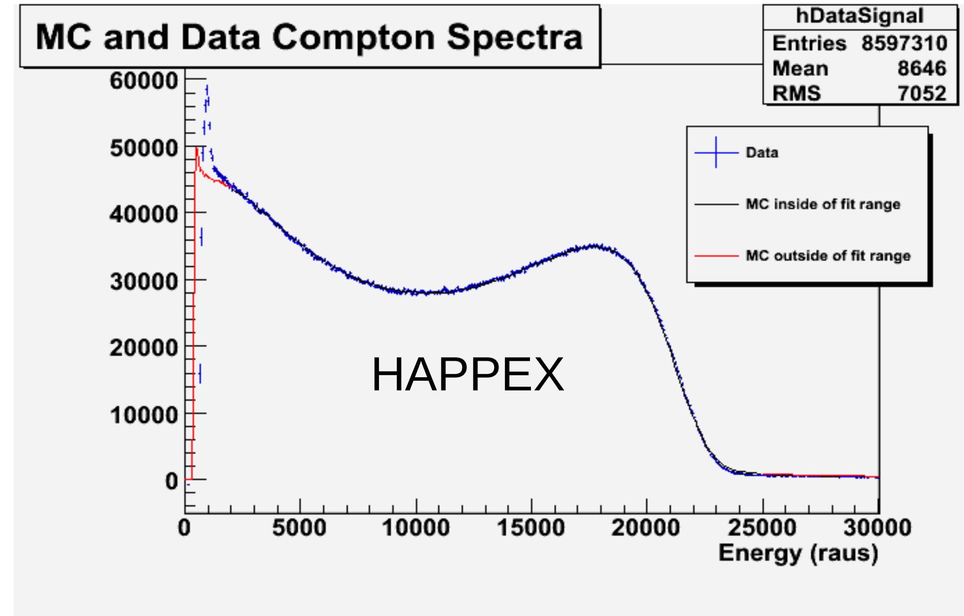
Inputs to the simulation:

- The experimental setup:
  - ➔Shielding, alignment.....
  - ➔Thickness of the lead shielding
  - ➔ Radius of the hole of the collimator
- Detector resolution, smearing
- Pileup Effect
- PMT nonlinearity

Analyzing Power / GEANT4 Monte Carlo



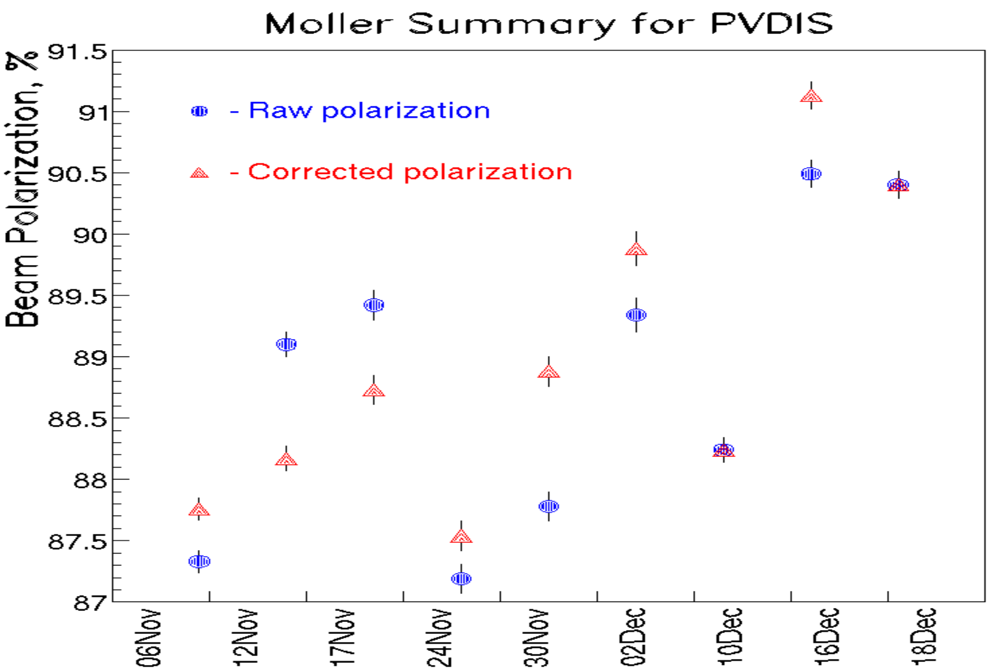




- Simulated spectrum sensitive to the thickness of lead shielding.
- Difference b/w best fit and real situation gives systematic error on analyzing power.

Beam Polarization (Compton/Moller)

$$A' = A_{measure} / Polarization$$

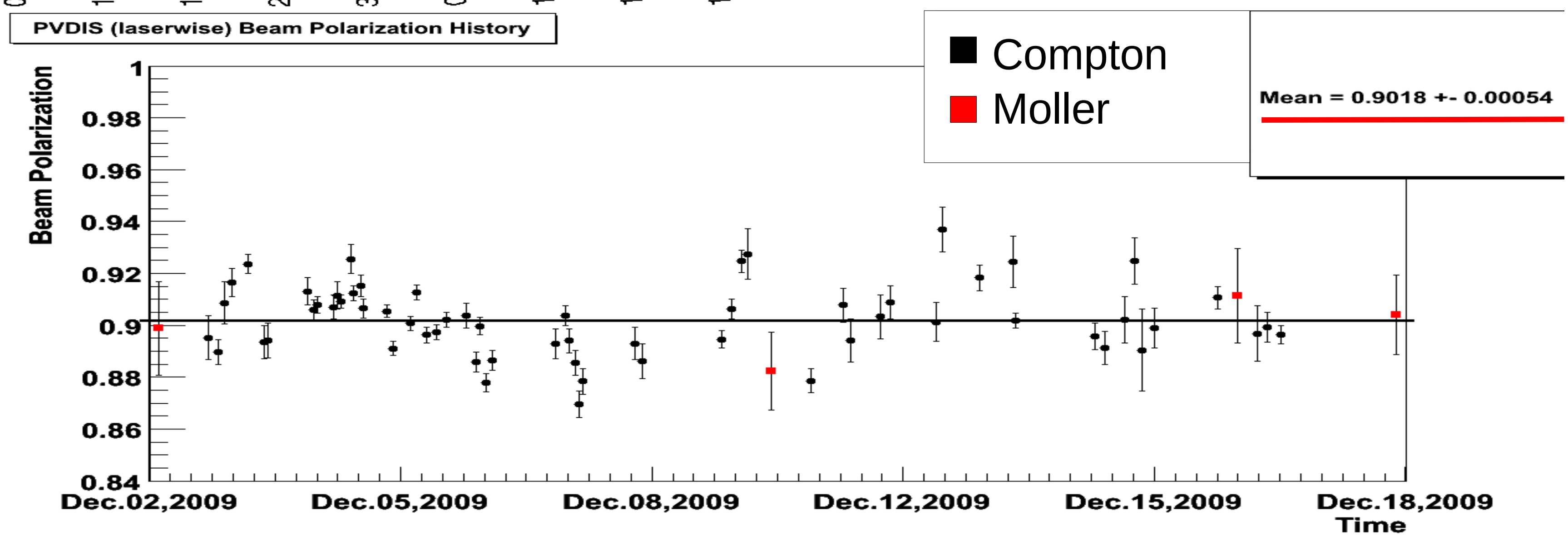


Moller: 88.47% +/- 2.0% (syst, relative) (6.0GeV)

90.4% +/- 1.7% (syst, relative) (4.8GeV)

Compton: 90.2% +/- 2.0% (syst, relative)

Systematic mainly from A_{th}

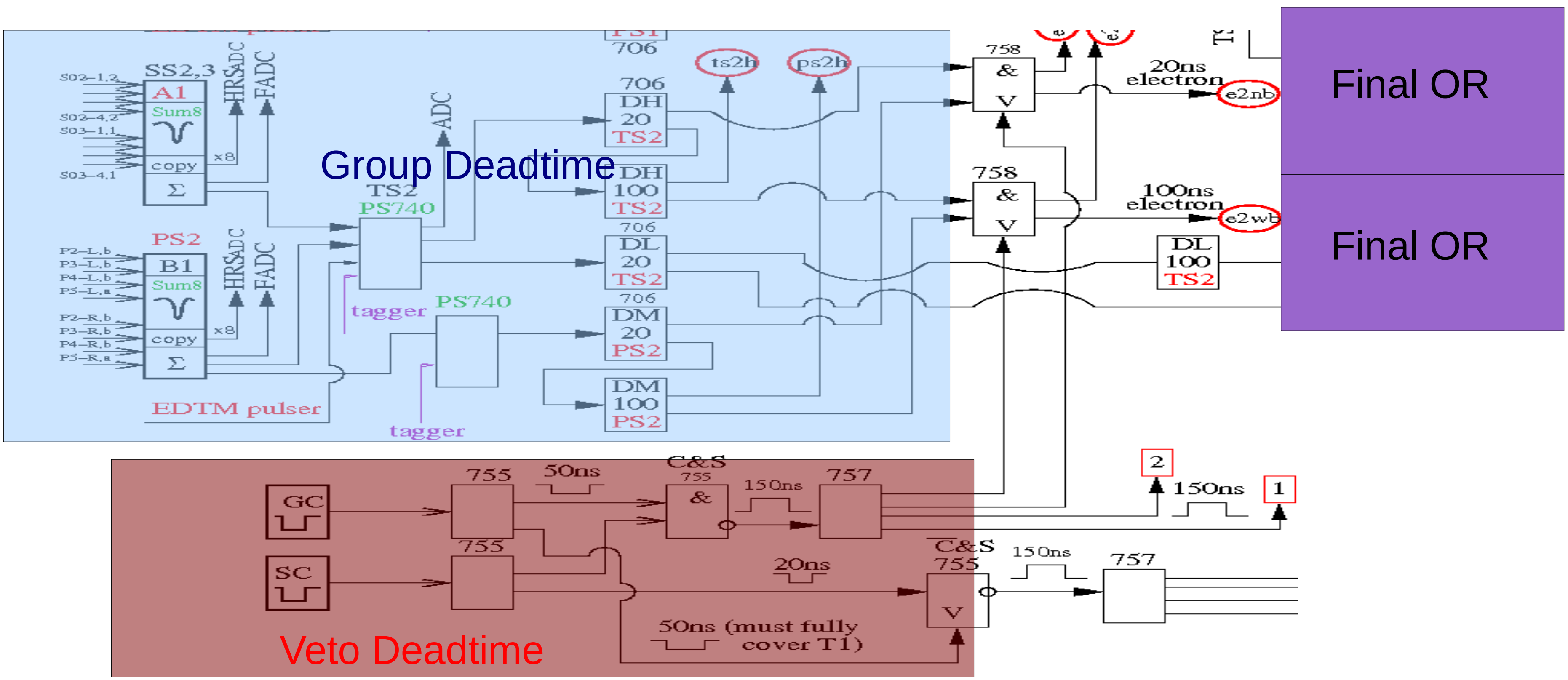


Deadtime Correction

Deadtime correction to asymmetry: $A' = A_{measure} / (1 - Deadtime)$

Deadtime Decomposition:

- Group Deadtime: proportional to group rate; narrow/wide path.
- Veto Deadtime: T1/GC rate; the same for all groups.
- Final OR: individual group triggers are ORed together to form final global trigger.
- Overall Deadtime: Veto DT $\oplus$ Group DT $\oplus$ Final OR DT



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Methods to study Deadtime:

- Theoretically, $Deadtime \propto Event\ Rate$
- FADC data: direct way to study veto deadtime, but low statistics.
- Tagger method: study group deadtime, compare with simulation.
- Software simulation: simulating all the signals and electronics, so everything. only way to get overall deadtime.

General Idea of Simulation

- ROOT/C++ Design;
- Simulates standard electronics (various electronic modules).
- Useful if you have a complex DAQ system (e.g. PVDIS).
- General idea:

  At every time instance (1ns), **Physics** information is generated. **Detectors** (**Leadglass**, **Gas Cerenkov**, **T1** ...) simulates the detector response and generates signals, which are processed by the **DAQ** system (constructed by **Modules**). **I/O** controls input and output.
- Inputs:
  - Leadglass (ADC) signals from data, then converted into analogy signal:

$$Analog\,signal \sim t \cdot e^{-\frac{t}{\tau}},\ where\ \tau\ needs\ to\ be\ calibrated$$

  - Physics signal rates. Also from data.
  - DAQ map.
- Output:
  - Rootfile containing all signal information with a time variable.
  - Can do post-hats analysis to get tdc spectrum, scaler counting, etc..
- It is NOT GEANT4 based, doesn't simulate particle interaction with materials.
- Efficiency: ~1hour to simulate 10ms. Maybe not fast enough for online monitoring...

Gene

- ROOT/C++ Design;
- Simulates standard electror
- Useful if you have a comple
- General idea:

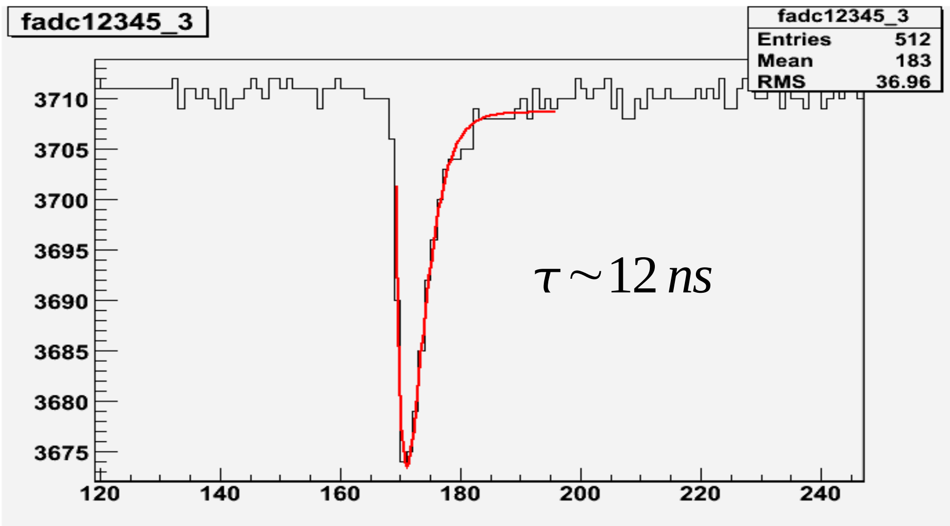
  At every time instance (
  Detectors (**Leadglass**,
  response and generates
  (constructed by **Module**
- Inputs:
  - Leadglass (ADC) signa

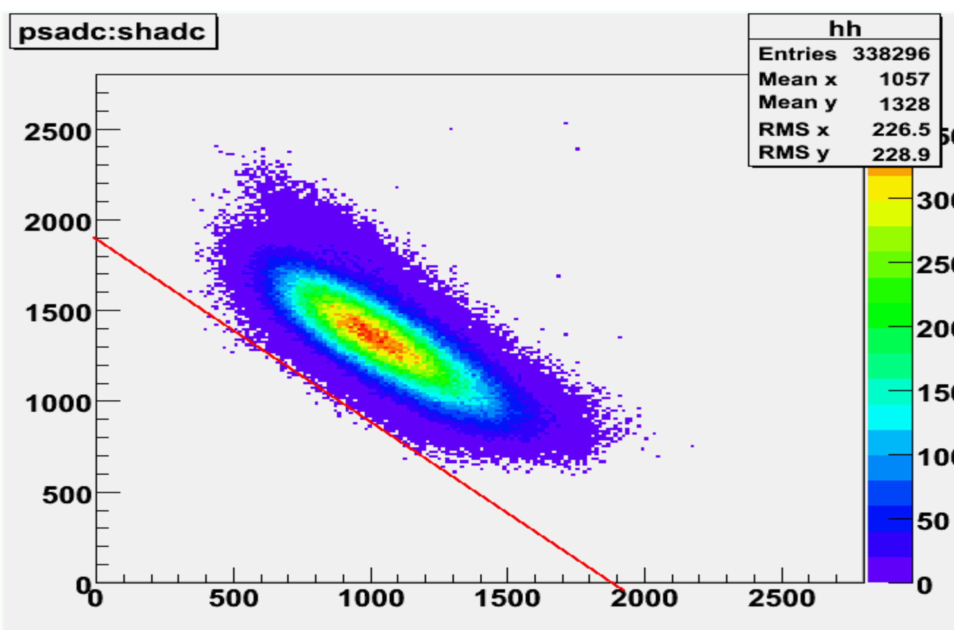
    Analog signal
  - Physics signal rates. A
  - **DAQ map.**
- Output:
  - Rootfile containing all s
  - Can do post-hats analy
- It is NOT GEANT4 based, c
- Efficiency: ~1hour to simula

```
#veto set up
250 GC rate 500000 width 60 output 0 13 1
251 T1 rate 500000 width 100 output 0 9 1
252 755 width 70 coinclvl 1 input 0 250 0 1 256 0 output 0 8 1 1 1 1 4 1 1
253 755 width 32 coinclvl 1 input 0 257 0 1 256 1 output 0 8 1 2 1 1
254 755 width 150 coinclvl 2 input 0 252 1 1 253 2 output 1 9 1 4 1 1
255 757 mode octal input 0 254 4 output 0 4 1 1 4 1
256 758 mode or width 18 input 0 299 0 output 0 28 1 1 28 1
#this is how we changed the T1 input width
257 706 threshold 100 width 30 input 0 251 0 output 0 4 1
#and we also changed the GC input width, well, from upstairs
#258 706 threshold 100 width 60 input 0 250 0 output 0 4 1

#other modules

#modules group 1
301 sum8 input 0 101 0 2 117 0 4 133 0 6 149 0 output 0 4 1
302 sum8 input 0 225 0 1 226 0 2 227 0 3 228 0 4 201 0 5 202 0 6 203 0 7 204 0 output 0 4 1 1 4 1
303 428F offset 0.0 input 0 301 0 1 302 0 2 2028 0 output 0 16 1
304 428F offset 0.0 input 0 302 1 1 2030 0 output 0 16 1
305 706 threshold 80 width 20 input 0 303 0 output 0 4 1 1 4 1
306 706 threshold 15 width 20 input 0 304 0 output 0 4 1 1 4 1
307 706 threshold 80 width 100 input 0 305 0 output 0 16 1 1 4 1
308 706 threshold 15 width 100 input 0 306 0 output 0 16 1 1 4 1
309 758 mode and width 16 veto 255 0 input 0 305 1 1 306 1 output 0 16 1 1 4 1 2 4 1
310 758 mode and width 16 veto 255 0 input 0 307 1 1 308 1 output 0 16 1 1 4 1 2 4 1

#modules group 2
401 sum8 input 0 102 0 1 103 0 2 118 0 3 119 0 4 134 0 5 135 0 6 150 0 7 151 0 output 0 4 1
402 sum8 input 0 227 1 1 228 1 2 229 0 3 230 0 4 203 1 5 204 1 6 205 0 7 206 0 output 0 4 1 1 4 1
403 428F offset 0.0 input 0 401 0 1 402 0 2 2028 1 output 0 16 1
404 428F offset 0.0 input 0 402 1 1 2030 1 output 0 16 1
405 706 threshold 80 width 20 input 0 403 0 output 0 4 1 1 4 1
406 706 threshold 15 width 20 input 0 404 0 output 0 4 1 1 4 1
407 706 threshold 80 width 100 input 0 405 0 output 0 16 1 1 4 1
408 706 threshold 15 width 100 input 0 406 0 output 0 16 1 1 4 1
409 758 mode and width 16 veto 255 0 input 0 405 1 1 406 1 output 0 16 1 1 4 1 2 4 1
410 758 mode and width 16 veto 255 0 input 0 407 1 1 408 1 output 0 16 1 1 4 1 2 4 1

#modules group 3
501 sum8 input 0 104 0 1 105 0 2 120 0 3 121 0 4 136 0 5 137 0 6 152 0 7 153 0 output 0 4 1
502 sum8 input 0 230 1 1 231 0 2 232 0 3 233 0 4 206 1 5 207 0 6 208 0 7 209 0 output 0 4 1 1 4 1
503 428F offset 0.0 input 0 501 0 1 502 0 2 2028 2 output 0 16 1
504 428F offset 0.0 input 0 502 1 1 2030 2 output 0 16 1
505 706 threshold 80 width 20 input 0 503 0 output 0 4 1 1 4 1
506 706 threshold 15 width 20 input 0 504 0 output 0 4 1 1 4 1
507 706 threshold 80 width 100 input 0 505 0 output 0 16 1 1 4 1
508 706 threshold 15 width 100 input 0 506 0 output 0 16 1 1 4 1
509 758 mode and width 16 veto 255 0 input 0 505 1 1 506 1 output 0 16 1 1 4 1 2 4 1
510 758 mode and width 16 veto 255 0 input 0 507 1 1 508 1 output 0 16 1 1 4 1 2 4 1
```

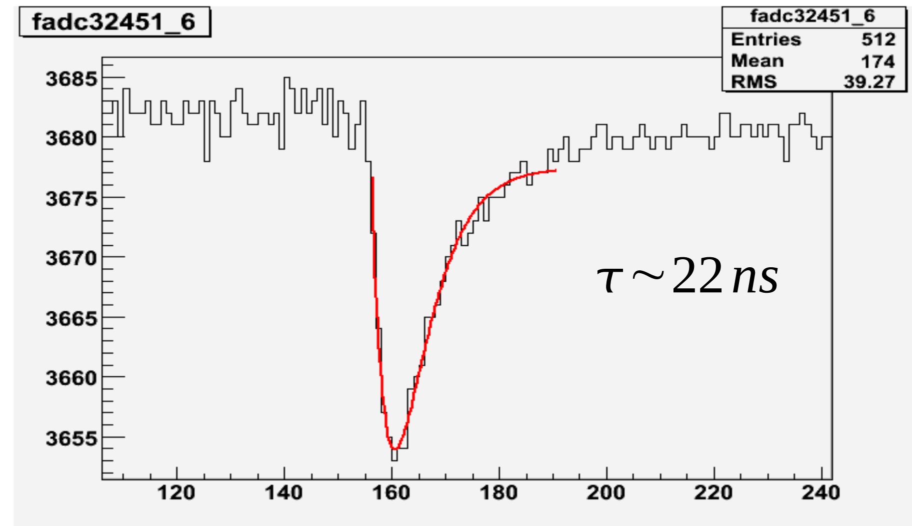
Time Constants Calibration

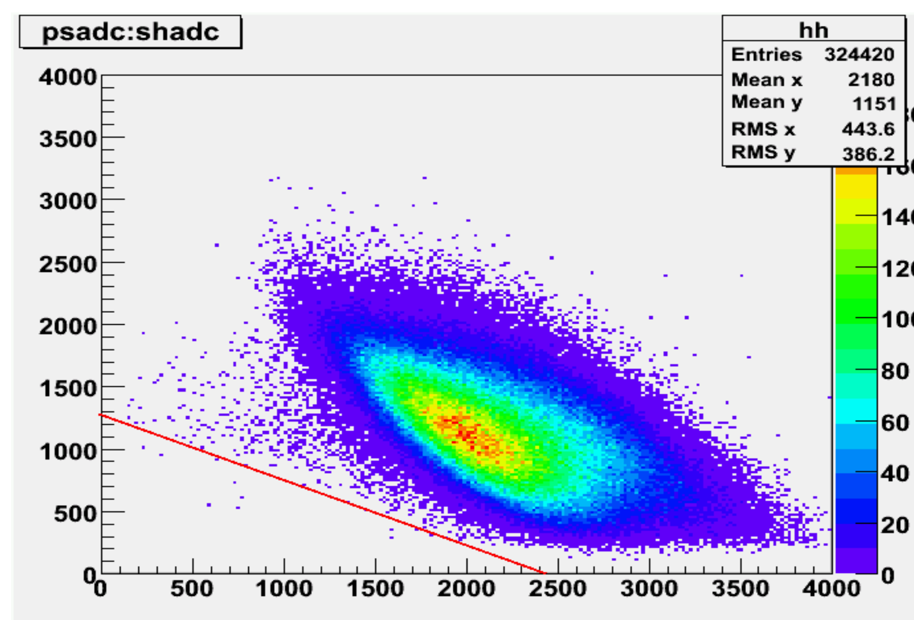
Right arm preshower PMTs:

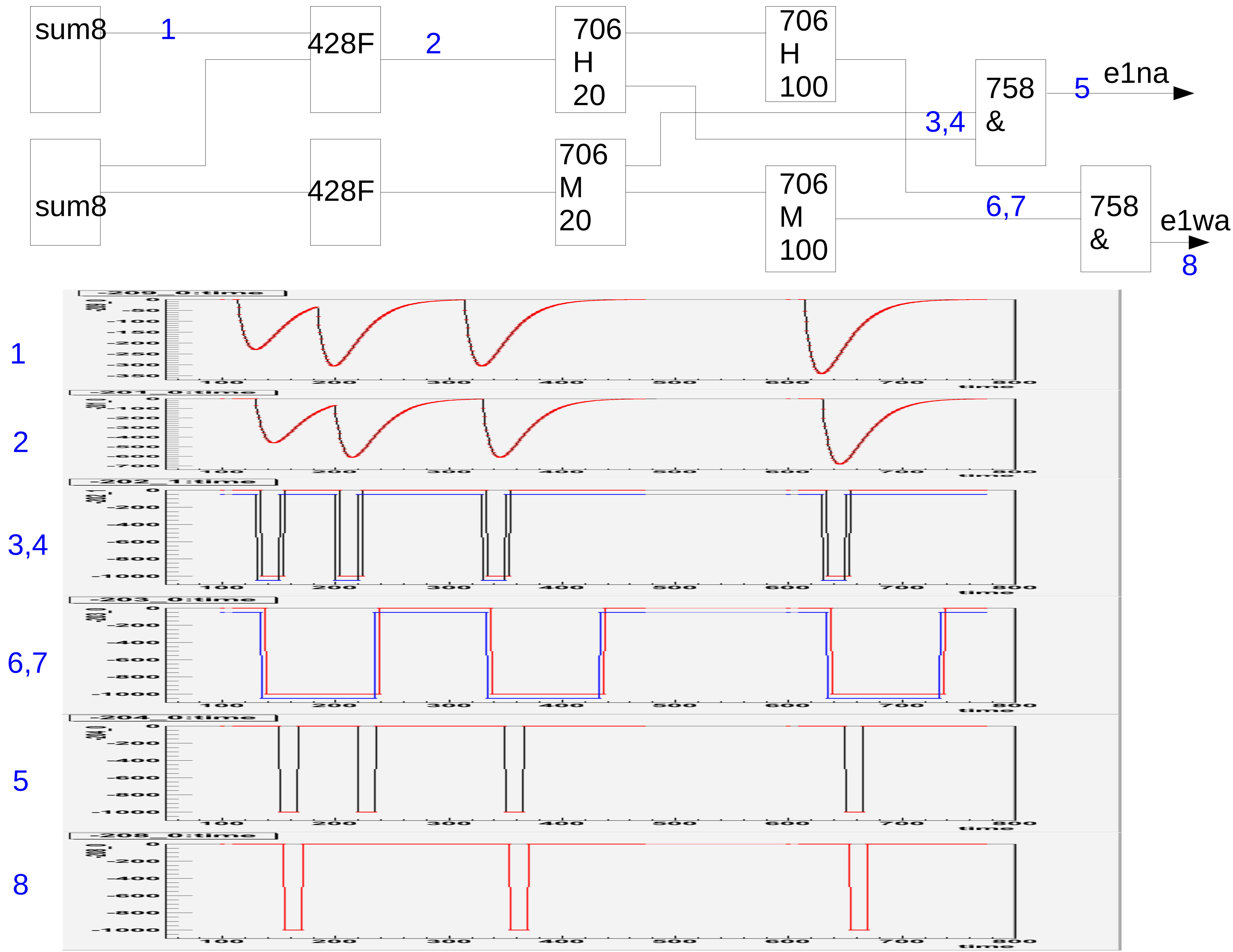




All Other Leadglass PMTs:

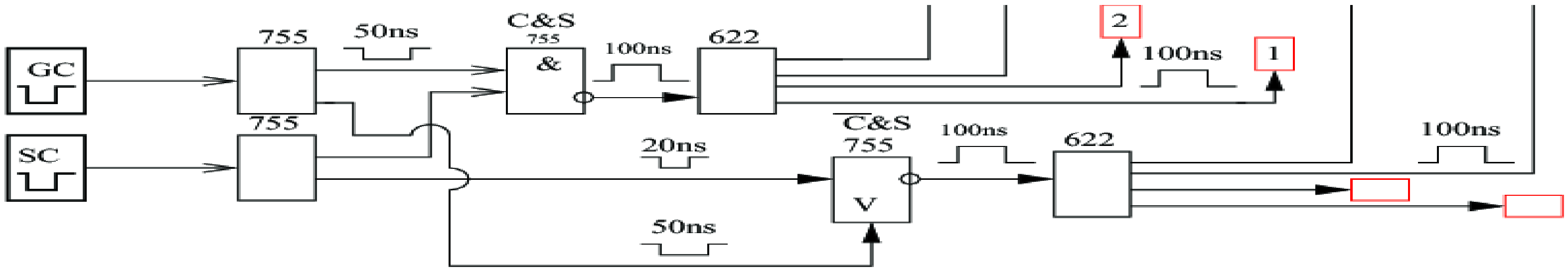


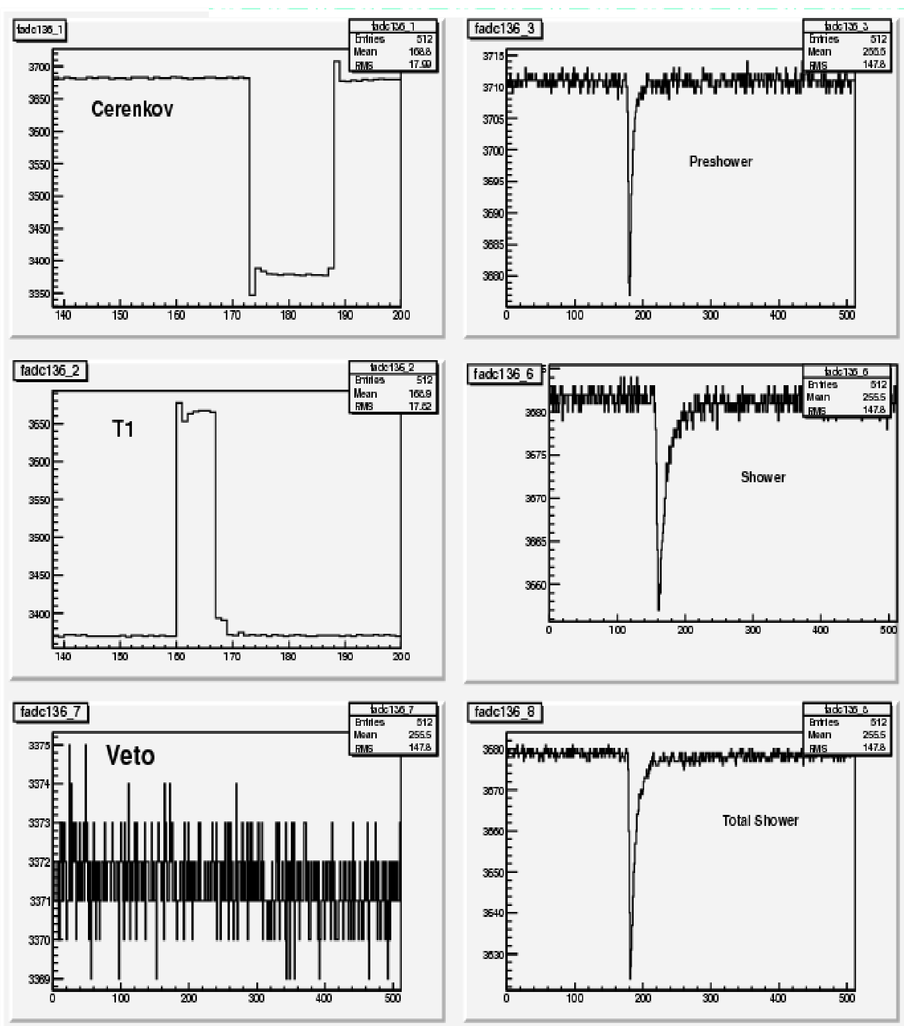


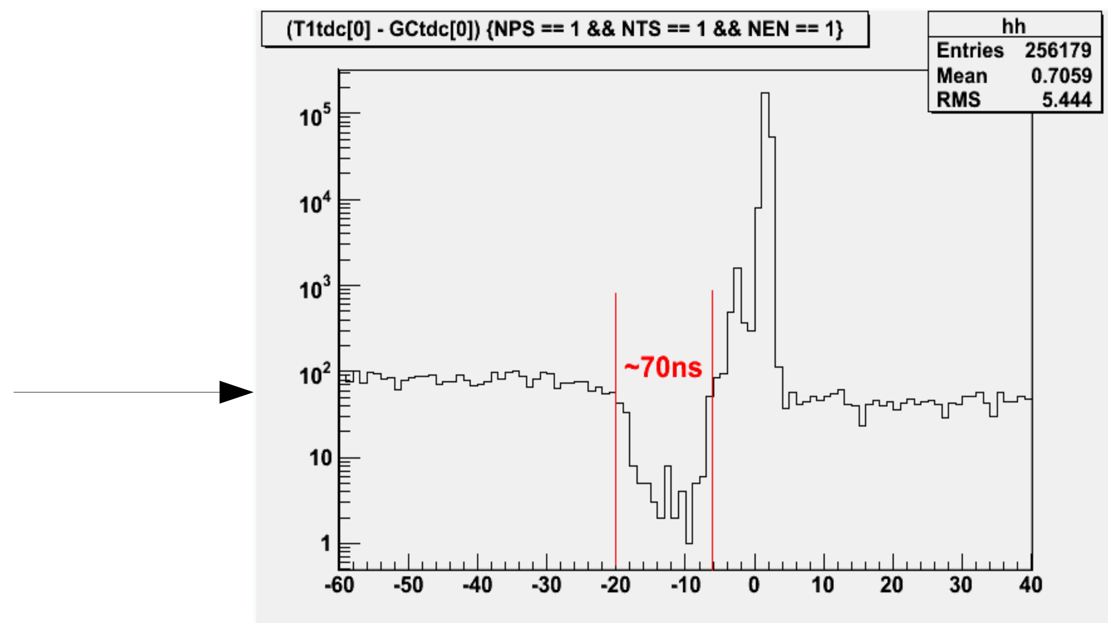


sum8
sum8
428F
428F
706 H 20
706 M 20
706 H 100
706 M 100
758 &
758 &
e1na
e1wa
1
2
3,4
5
6,7
8

Veto Deadtime/FADC Analysis



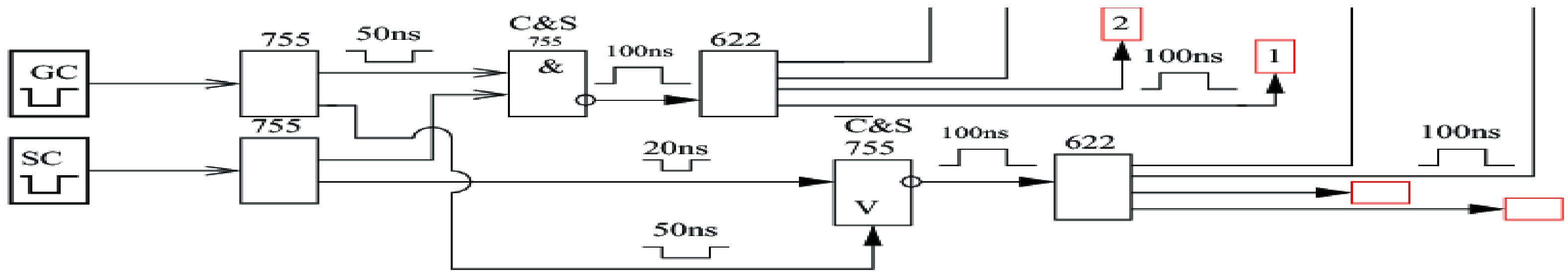


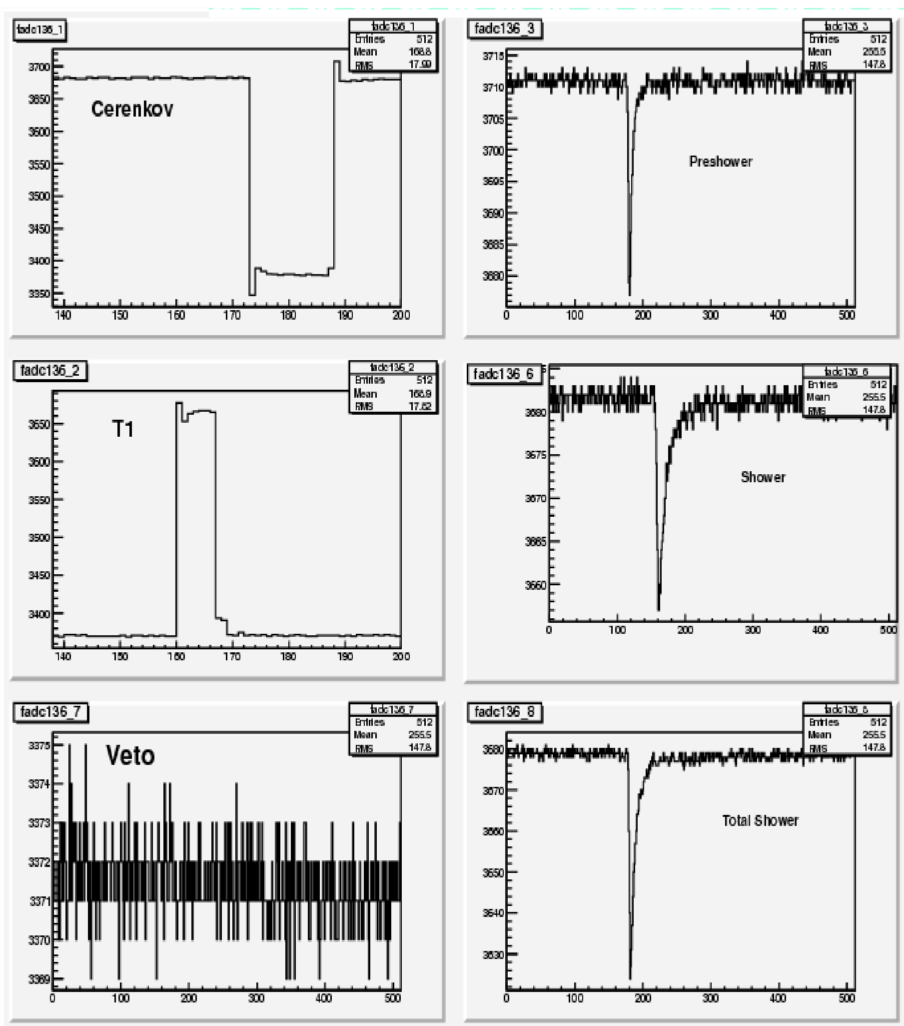


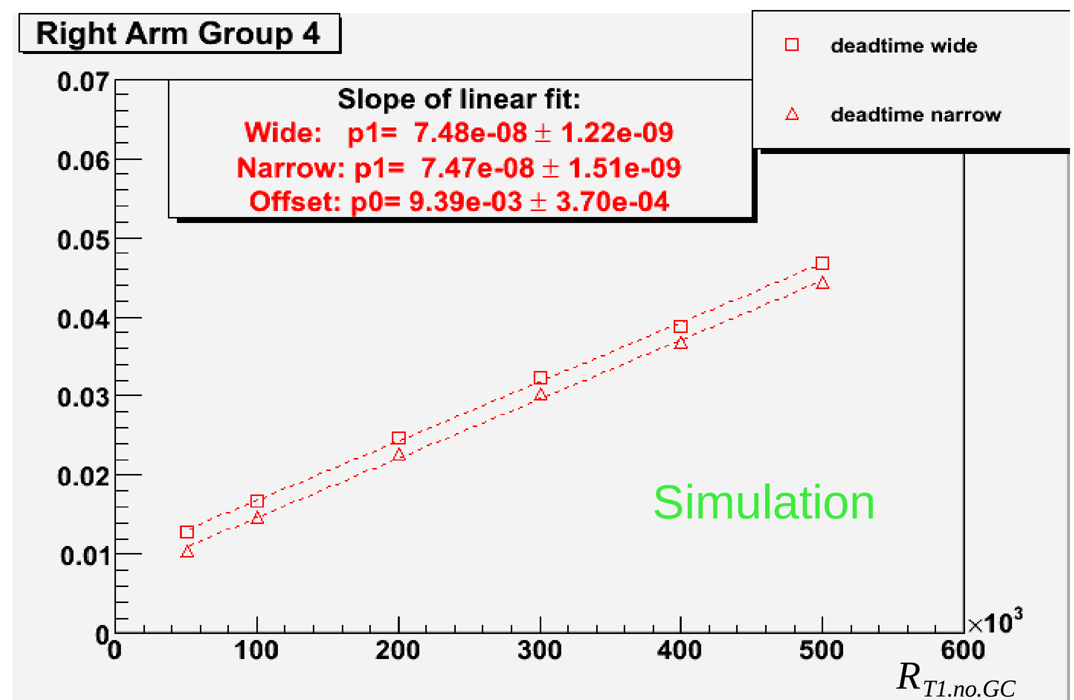
$$Veto\ Deadtime = R_{T1.no.GC} \times (W_{T1in} - W_{T1out})$$

Veto Deadtime is the same for narrow/wide path

Veto Deadtime/FADC Analysis







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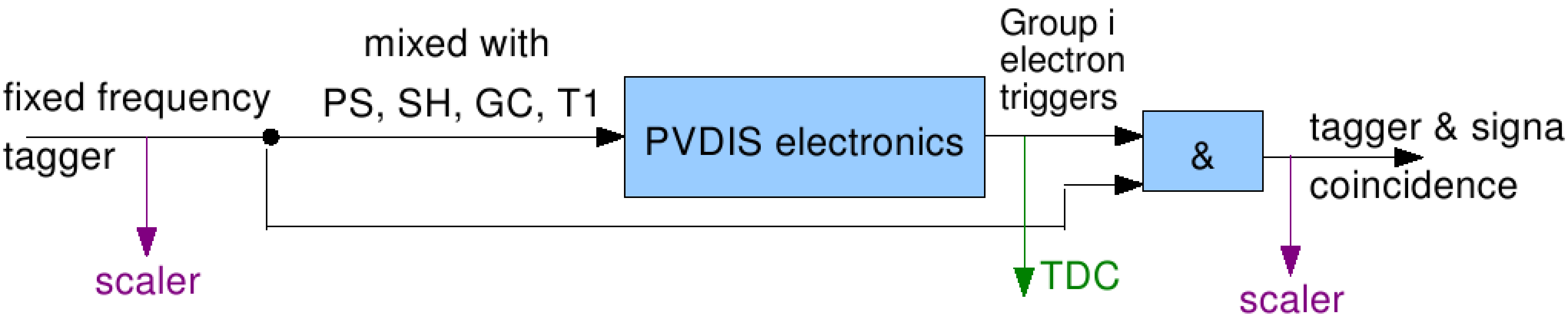
Path Deadtime/Tagger Analysis

The Tagger method to measure deadtime:



$$Deadtime = \frac{R_{tagger} - R_{tagger\,\&\,signal}(1 - Pileup)}{R_{tagger}} \approx \frac{R_{tagger} - R_{tagger\,\&\,signal}}{R_{tagger}} + Pileup$$

$$\equiv Fractional\ Loss + Pileup$$

Measured by scaler
Different for narrow and wide path

Measured by TDC
Same for narrow and wide path

Path Deadtime/Tagger Analysis

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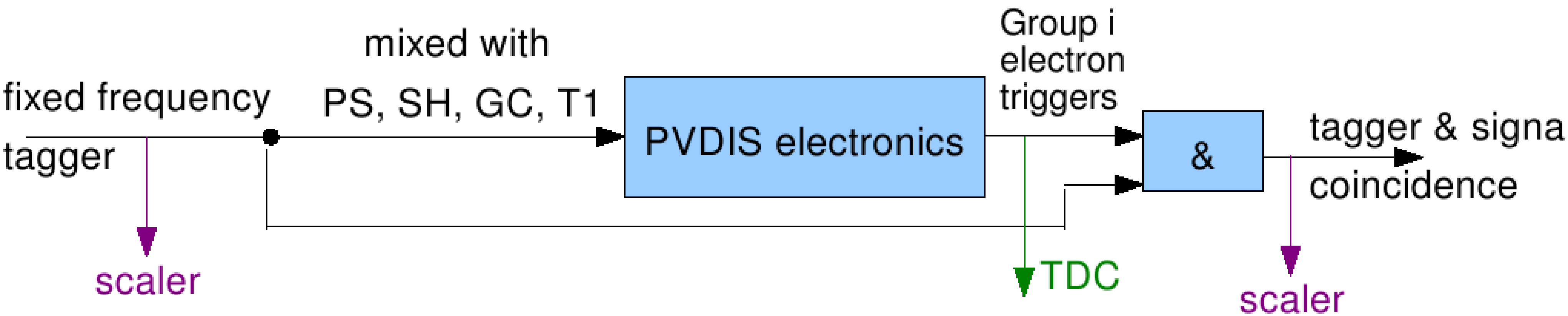

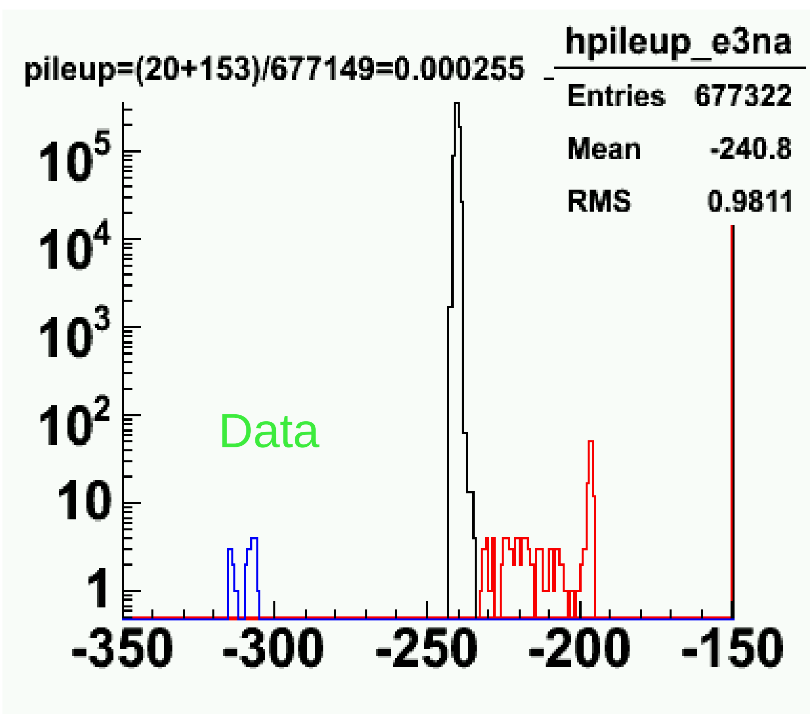

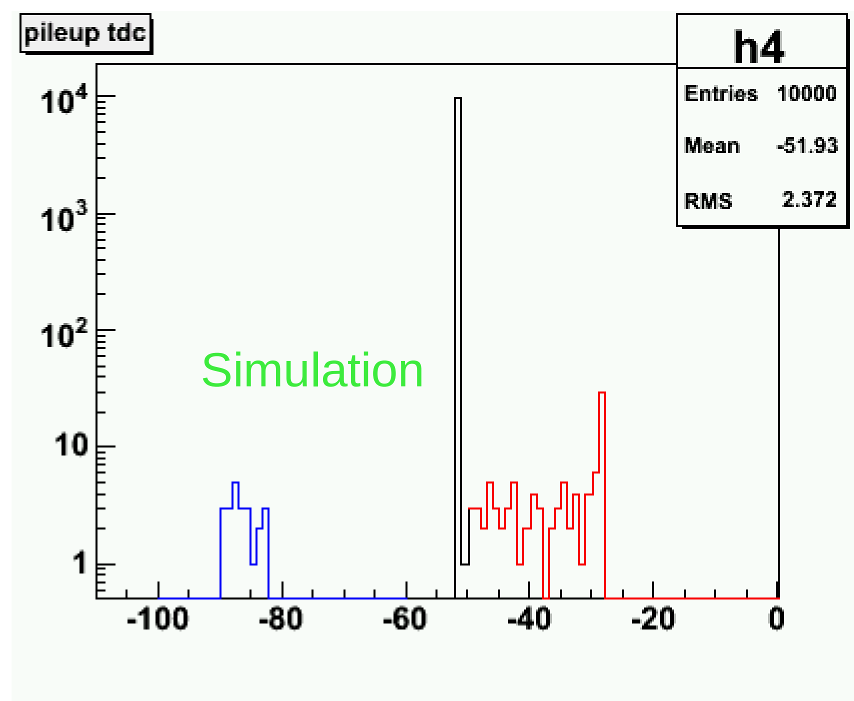

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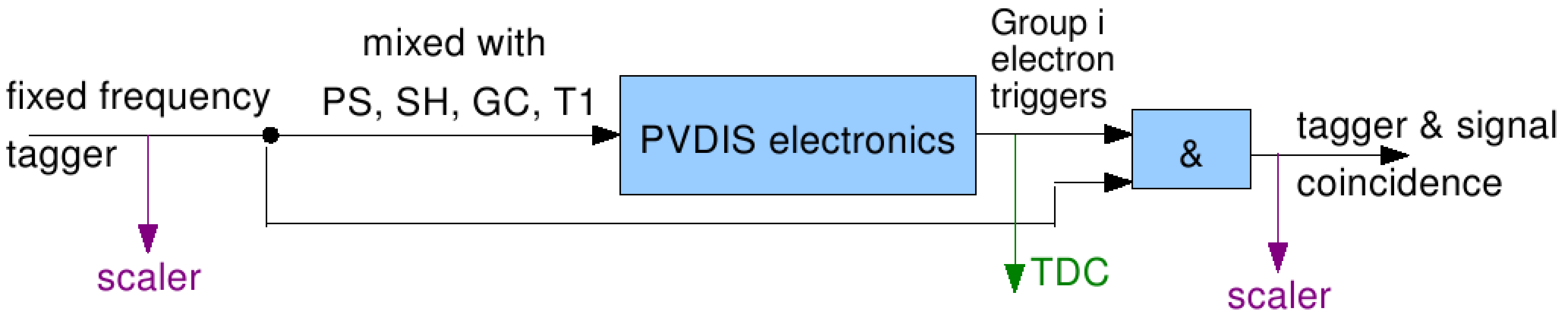
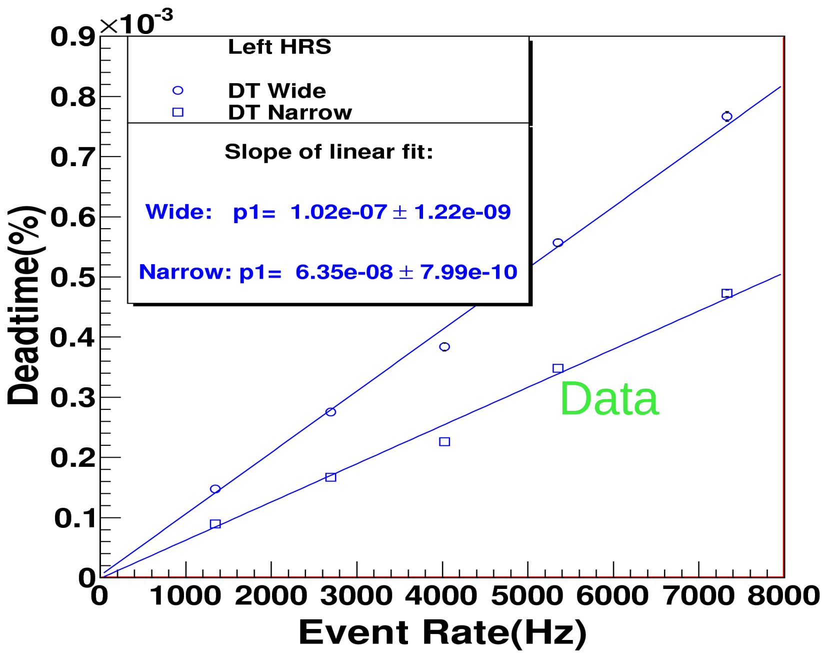
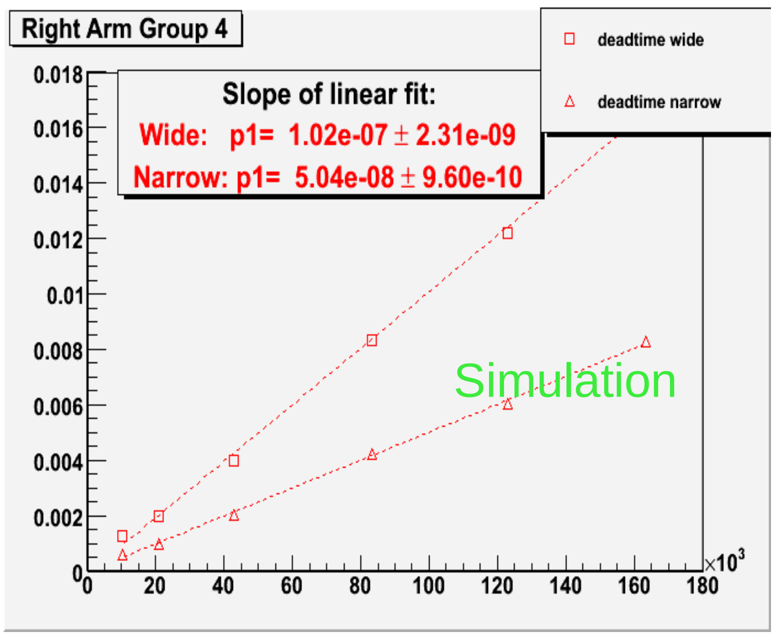
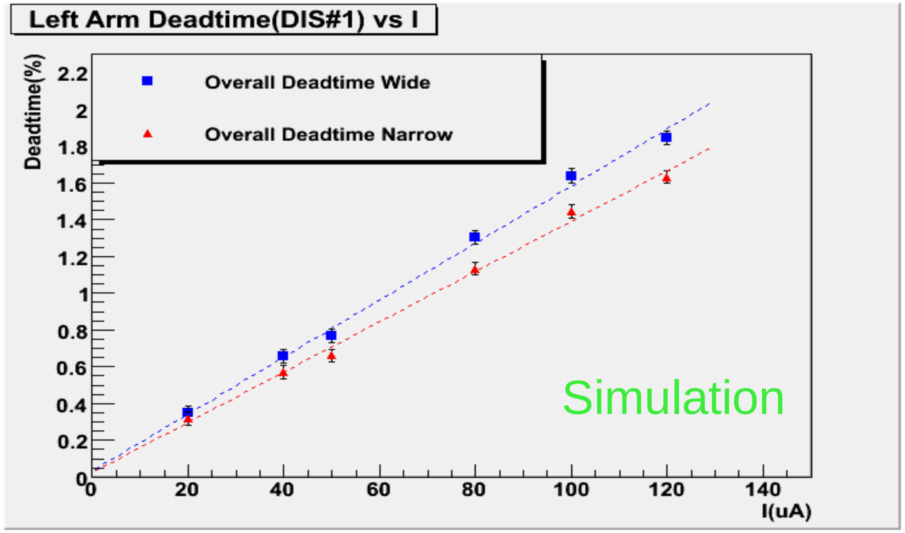


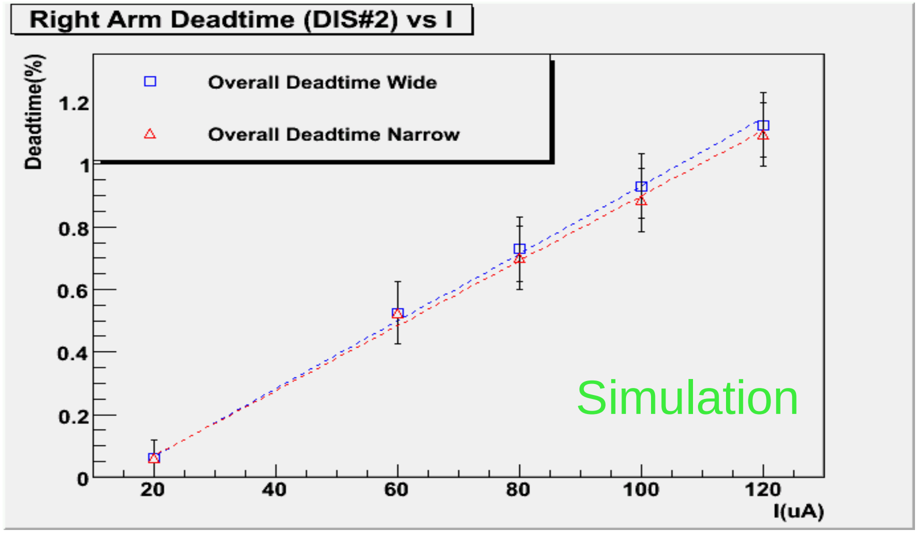




Deadtime Correction

Overall Deadtime:

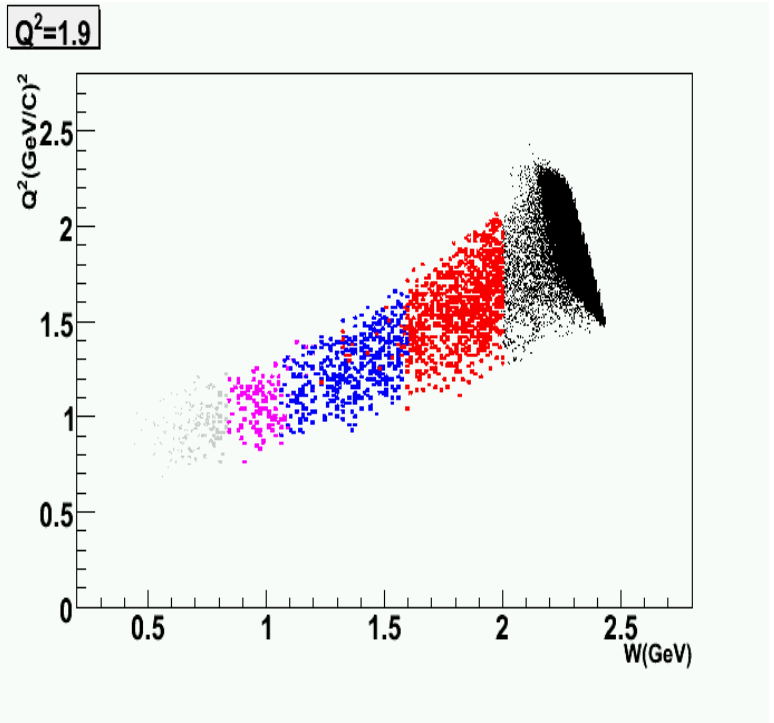




@100uA	RES #3	RES #4	RES #5	RES #7	DIS #1	DIS #2
Narrow	1.48% +/- 0.44%	2.22% +/- 0.67%	2.06% +/- 0.62%	0.73% +/- 0.22%	1.45% +/- 0.44%	0.89% +/- 0.27%
Wide	1.68% +/- 0.5%	2.62% +/- 0.79%	2.36% +/- 0.71%	0.8% +/- 0.24%	1.64% +/- 0.49%	0.93% +/- 0.28%

EM Radiative Corrections

- Based on Hall A Monte Carlo (HAMC)
- Prerequisites:
  - Radiation: Internal/External Bremsstrahlung, Ionization....
  - Acceptance
  - Simulation checked with data



- Inputs:

■ DIS: calculated using PDF fits (MRST/CTEQ).

■ Elastic ■ Quasi-Elastic : Data/Theoretical calculations

Resonance:

Some calculation (Misha Gorshteyn), which covers a large part of the resonance

■ Delta Resonance: Theoretical calculation (Lee & Tao).

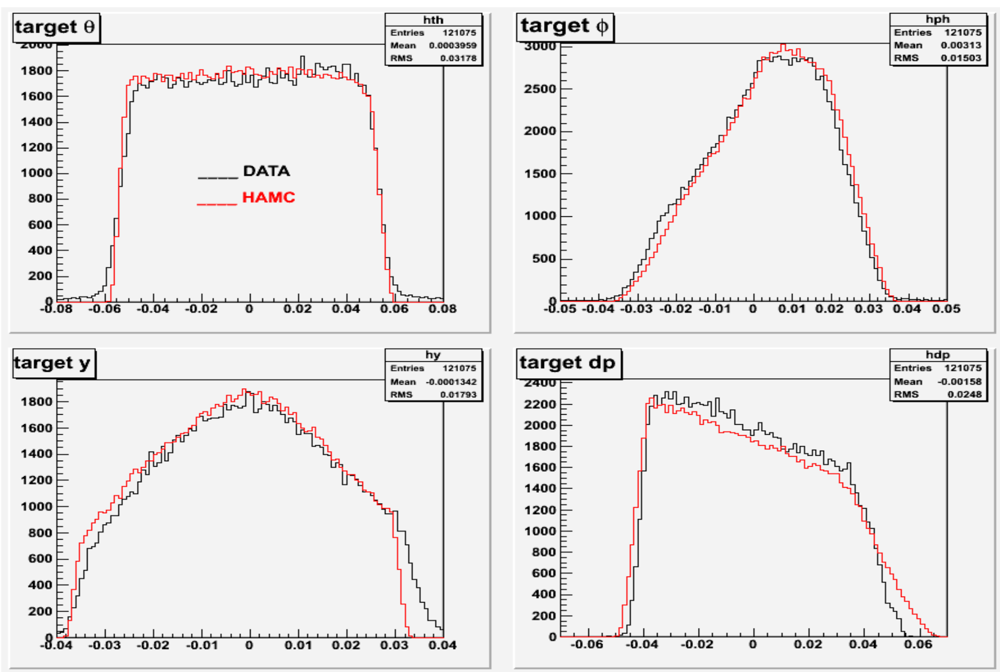
■ Other Resonance: No previous data
"Toy Model", eg. $A_{toy} = A_{dis} \times \frac{\sigma_{res}}{\sigma_{dis}}$

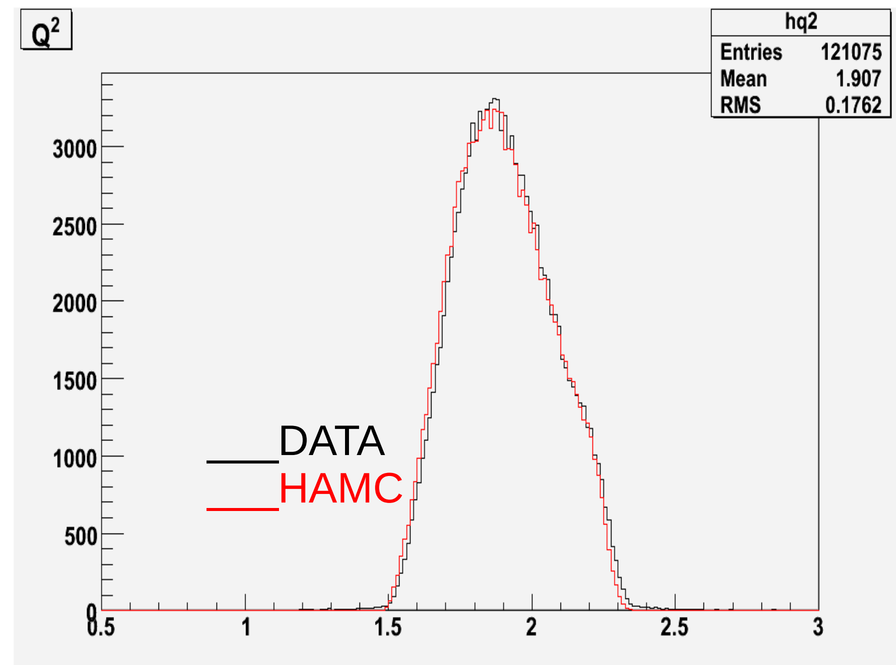
Use resonance data to constrain uncertainties.

Hall A Monte Carlo

A Monte Carlo simulation package developed to simulate the physics.

Basic checks of HAMC:



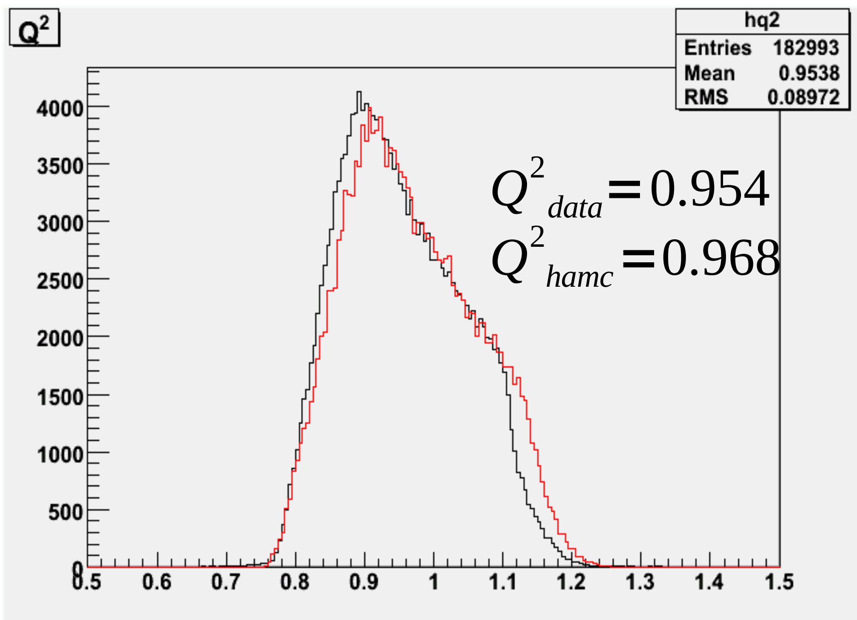


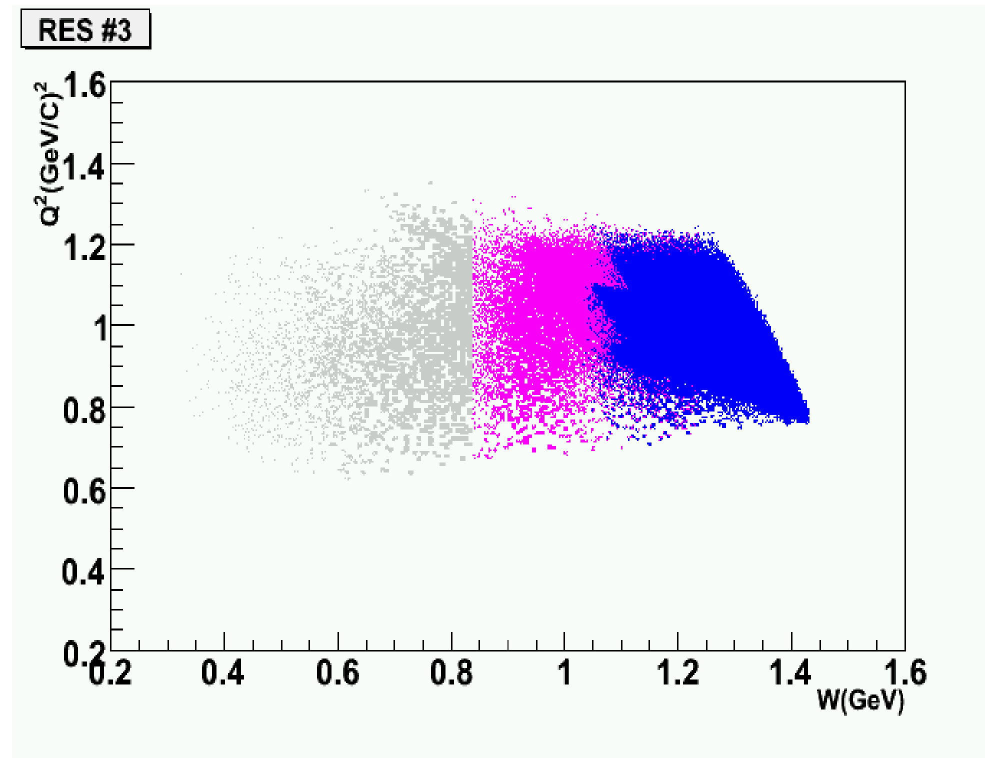
$$Q^2_{data} = 1.907$$

$$Q^2_{hamc} = 1.896$$

Res #3 / Delta Resonance

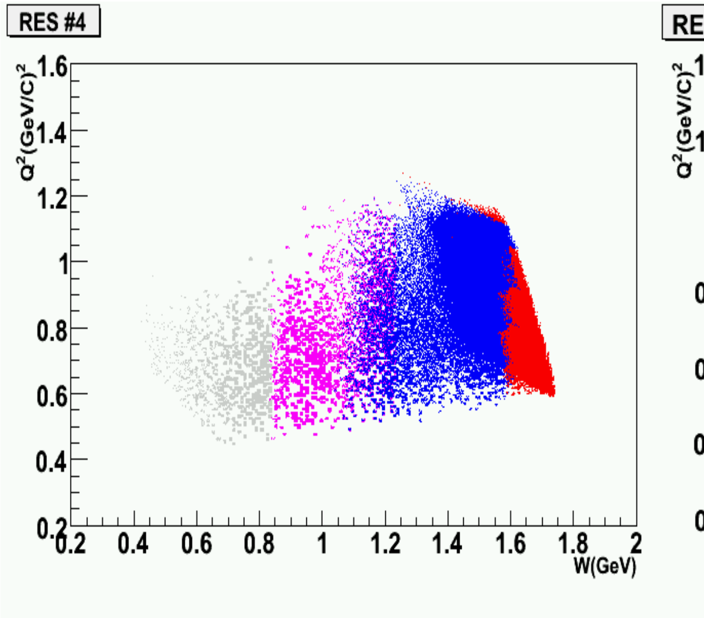
(Magnets Mistuned)

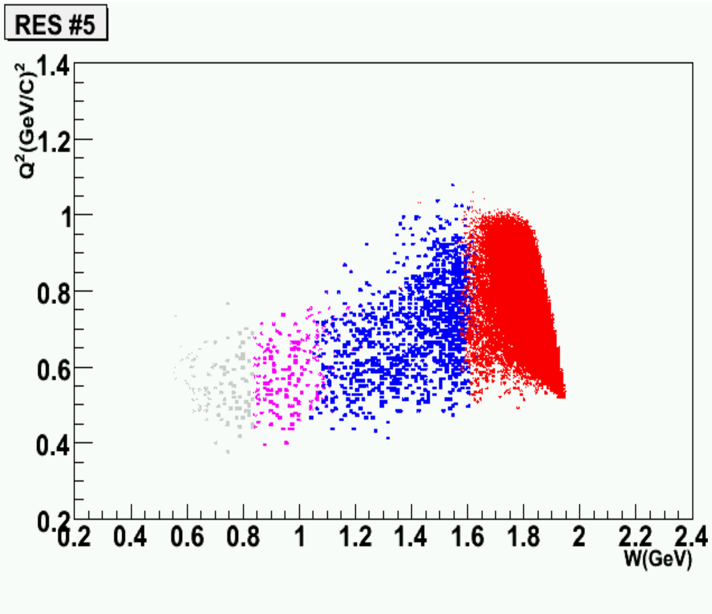


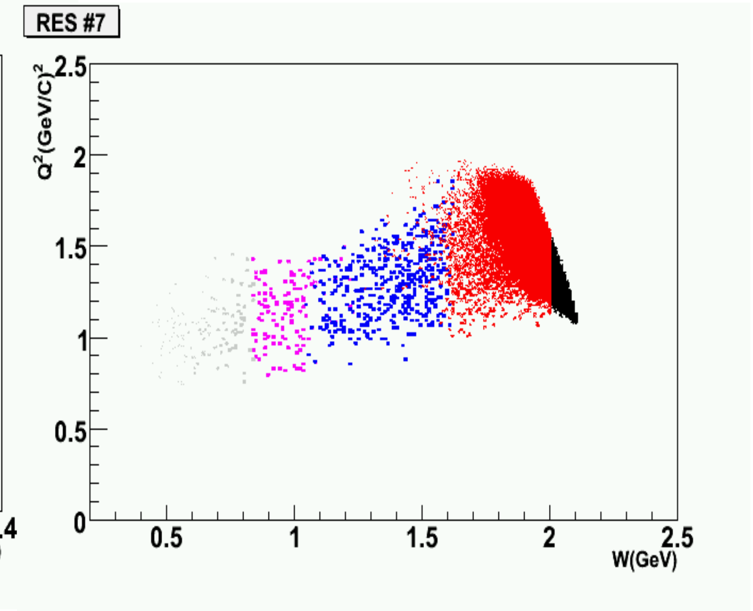


	Elastic	Quasi	Table	Dis	Toy	<Asym>	Data
Lee&Tao	80.2 (0.15%)	-46.4 (12.5%)	-89.3 (87.4%)	0	0	-83.66(ppm)	-66.258 +/-7.768 (ppm)
Misha	80.3 (0.16%)	-46.5 (12.2%)	-89.2 (87.6%)	0	0	-83.68(ppm)	

Resonance #4,5,7 / Toy Model

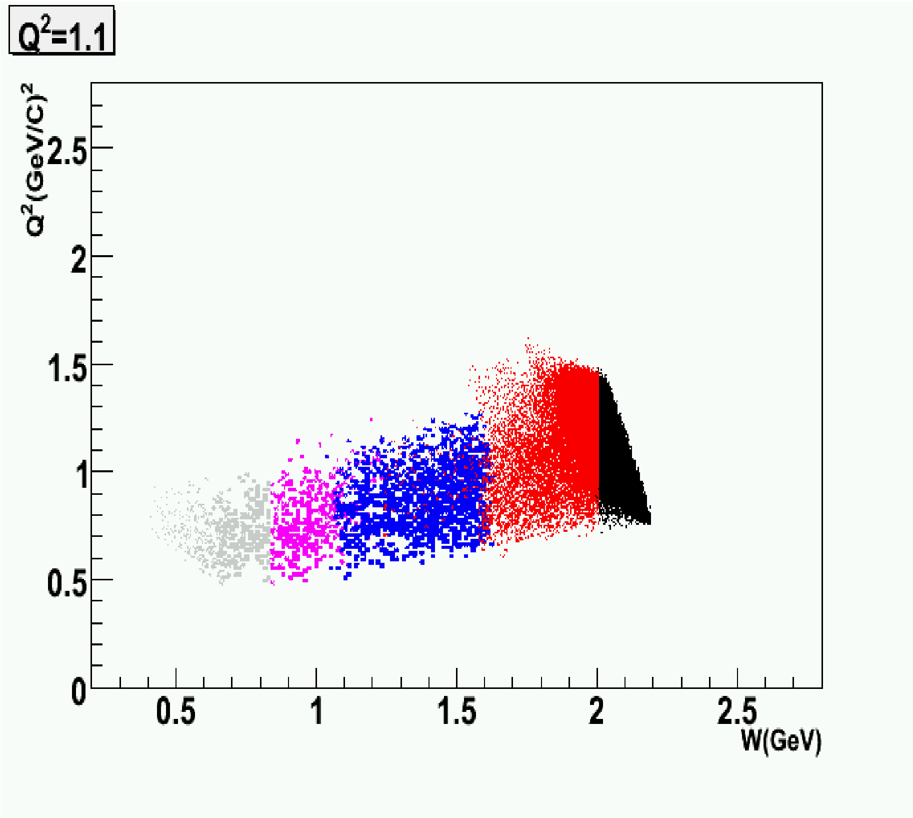


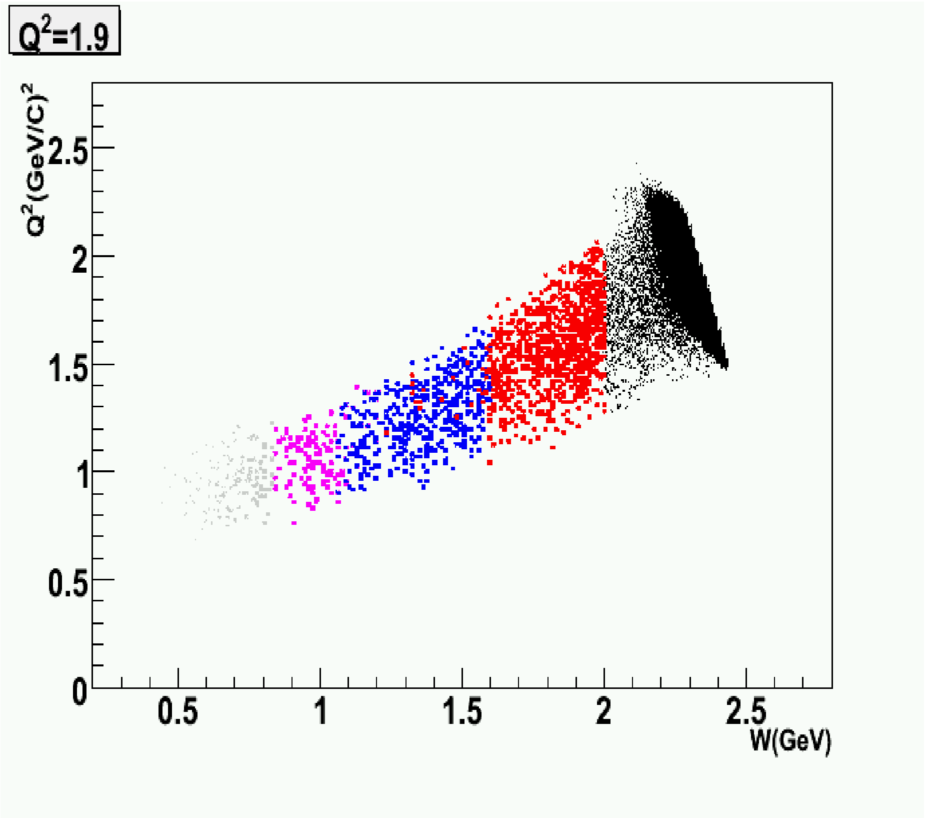




	Elastic	Quasi	Delta	Dis	Toy	<Asym>	Data
Res #4	54.9 (0.04%)	-25.6 (1.7%)	-67.0 (72.2%)	0	-62.7 (26.1%)	-65.2 (ppm)	-73.4+/-6.9 (ppm)
Res #5	43.8 (0.02%)	-18.9 (1.3%)	-55.2 (3.7%)	0	-59.7 (95.0%)	-59.0 (ppm)	-60.9 +/- 5.15 (ppm)
Res #7	86.4 (0.04%)	-47.5 (0.8%)	-101.2 (1.6%)	-105.6 (21.7%)	-120.7 (75.9%)	-116.4 (ppm)	-118.8 +/- 16.9 (ppm)

DIS Radiative Corrections





	Elastic	Quasi	Delta	Dis	Toy	<Asym>	A_central	Correction Factor
Dis #1	58.4 (0.03%)	-26.9 (1.3%)	-68.3 (2.1%)	-85.2 (61.1%)	-94.6 (35.4%)	-87.4 (ppm)	-91.7 (ppm)	1.049
Dis #2	80.7 (0.05%)	-46.4 (0.897%)	-102.4 (1.46%)	-157.0 (95.5%)	-126.2 (2.03%)	-154.4 (ppm)	-161.7 (ppm)	1.047

Thank You!