Parity Violating Deep Inelastic Scattering at 6 GeV

Xiaoyan Deng
University of Virginia
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- The Physics of PVDIS
- Experimental Setup and General Run Information
- Online Results and Expected Uncertainties
- On-Going Data Analysis
  - BCM Calibration
  - Deadtime of the Fast-Counting DAQ
- Summary

The Physics of PVDIS at 6 GeV (E08-011)

Measure PVDIS asymmetry on a deuterium target, A_d, at Q^2=1.10 and 1.90 GeV^2 to 2% (stat.);

$$A_{pv} \equiv \frac{\sigma^r - \sigma^l}{\sigma^r + \sigma^l} = \frac{(M_\gamma + M_Z^r)^2 - (M_\gamma + M_Z^l)^2}{(M_\gamma + M_Z^r)^2 + (M_\gamma + M_Z^l)^2} \approx \frac{M_Z^r - M_Z^l}{M_\gamma}$$

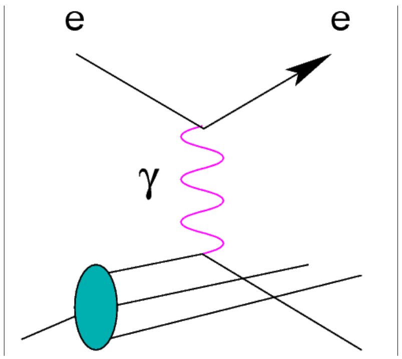
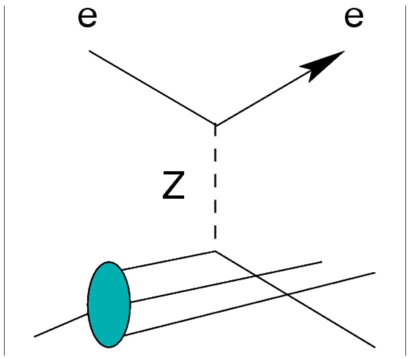
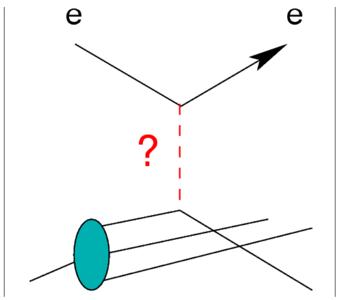
From Q^2=1.10 can help to investigate if there are significant HT effects;

— "Baseline" measurement for the future 12 GeV program.

If HT is small, from Q^2=1.90 GeV^2 can extract $2C_{2u}-C_{2d}$ to ±0.060, a factor of 4.1 improvement

Kinematics	x_{bj}	Q^2 $(GeV/c)^2$	E_{beam} (GeV)	E' (GeV)	θ(°)	W^2 $(GeV)^2$	A_d (ppm)
I	0.25	1.11	6.0	3.66	12.9°	4.16	-91.3
II	0.3	1.9	6.0	2.63	20.0°	5.3	-160.7

PVDIS Asymmetries

$A_{PV} =$  +  + 

Deuterium:

$$A_d = (540\ ppm) Q^2 \frac{2C_{1u}[1+R_C(x)] - C_{1d}[1+R_S(x)] + Y(2C_{2u} - C_{2d})R_V(x)}{5 + R_S(x) + 4R_C(x)}$$

$$C_{1u} = g_A^e g_V^u = -\frac{1}{2} + \frac{4}{3}\sin^2(\theta_W) \qquad C_{2u} = g_V^e g_A^u = -\frac{1}{2} + 2\sin^2(\theta_W)$$

$$C_{1d} = g_A^e g_V^d = \frac{1}{2} - \frac{2}{3}\sin^2(\theta_W) \qquad C_{2d} = g_V^e g_A^d = \frac{1}{2} - 2\sin^2(\theta_W)$$

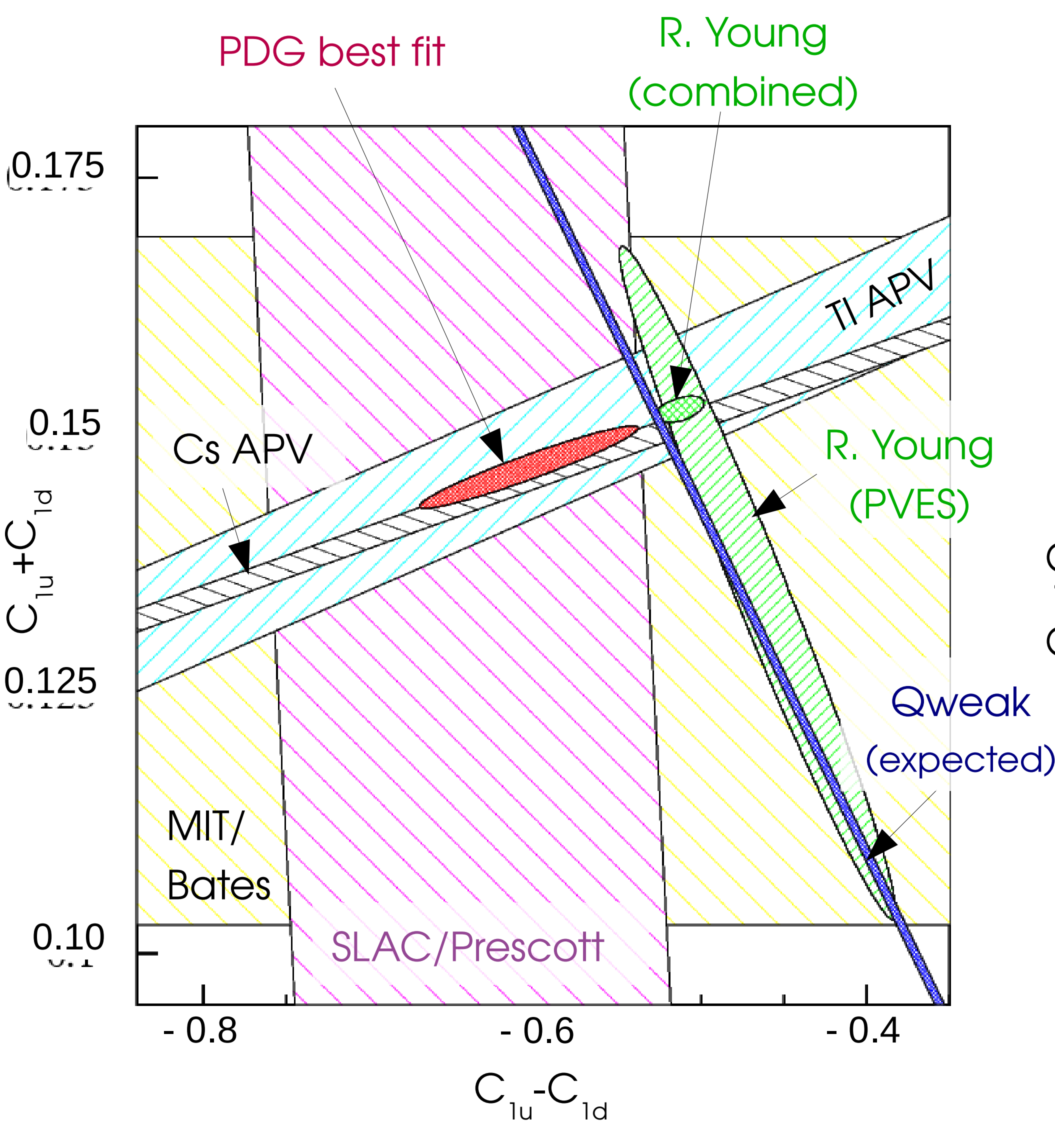
Can extract $C_{1,2q}$ (and $\sin^2\theta_W$)– discover new physics beyond the SM

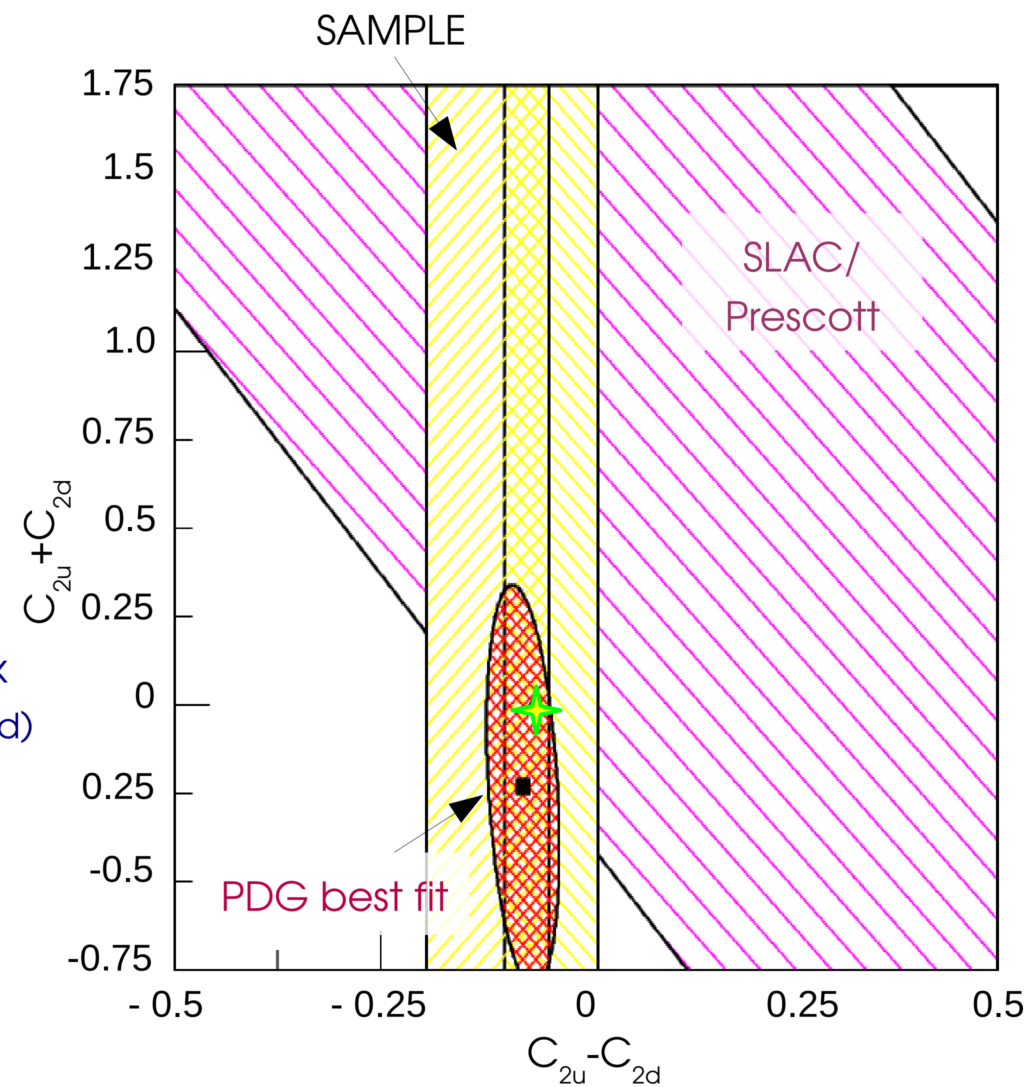
Mass limit:

$$\Lambda / g \approx \frac{1}{\left[\sqrt{8}\, G_F \left|\Delta(2C_{2u} - C_{2d})\right|\right]^{1/2}} \approx 0.74\ \text{TeV}$$

Current Knowledge on $C_{1,2q}$

all are 1 σ limit

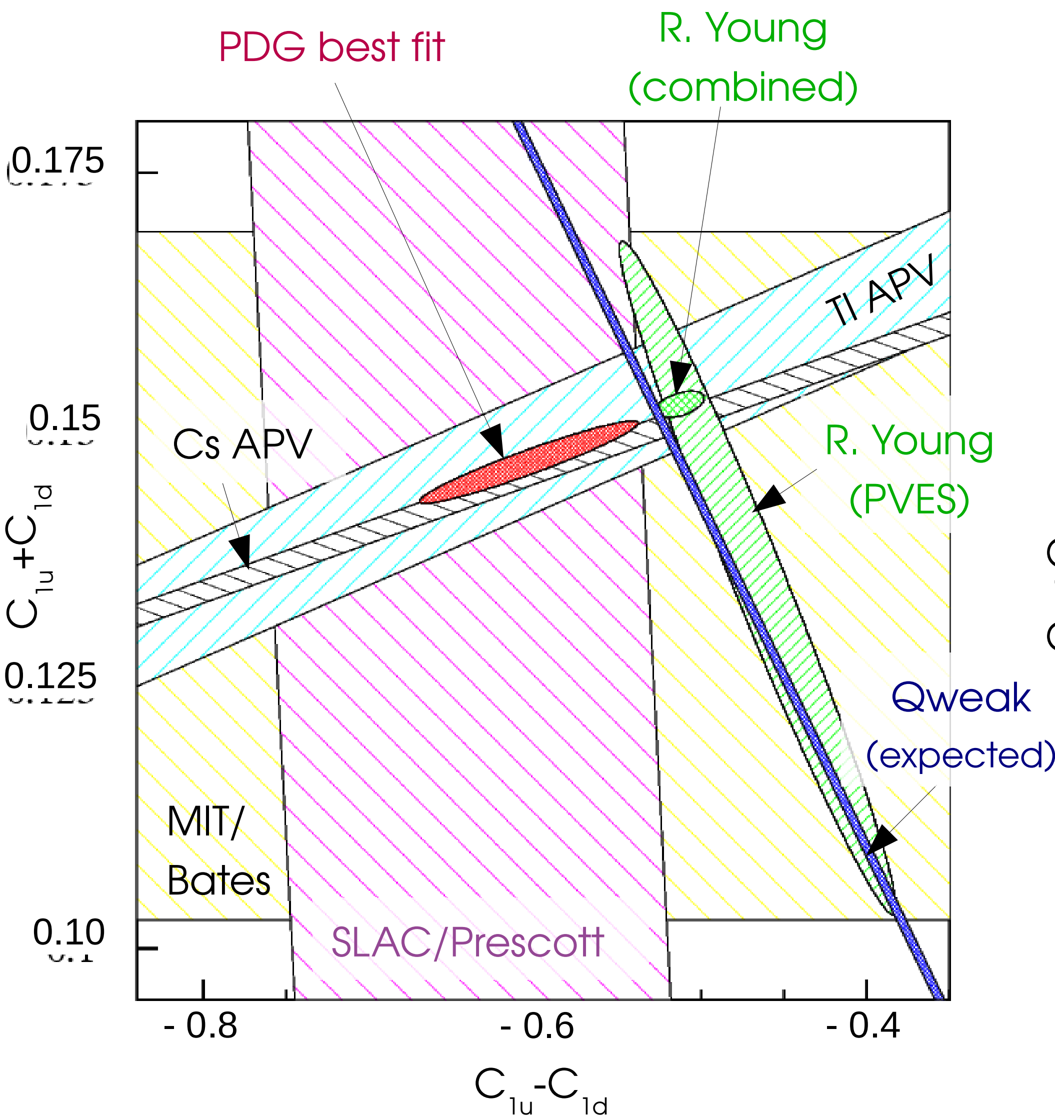


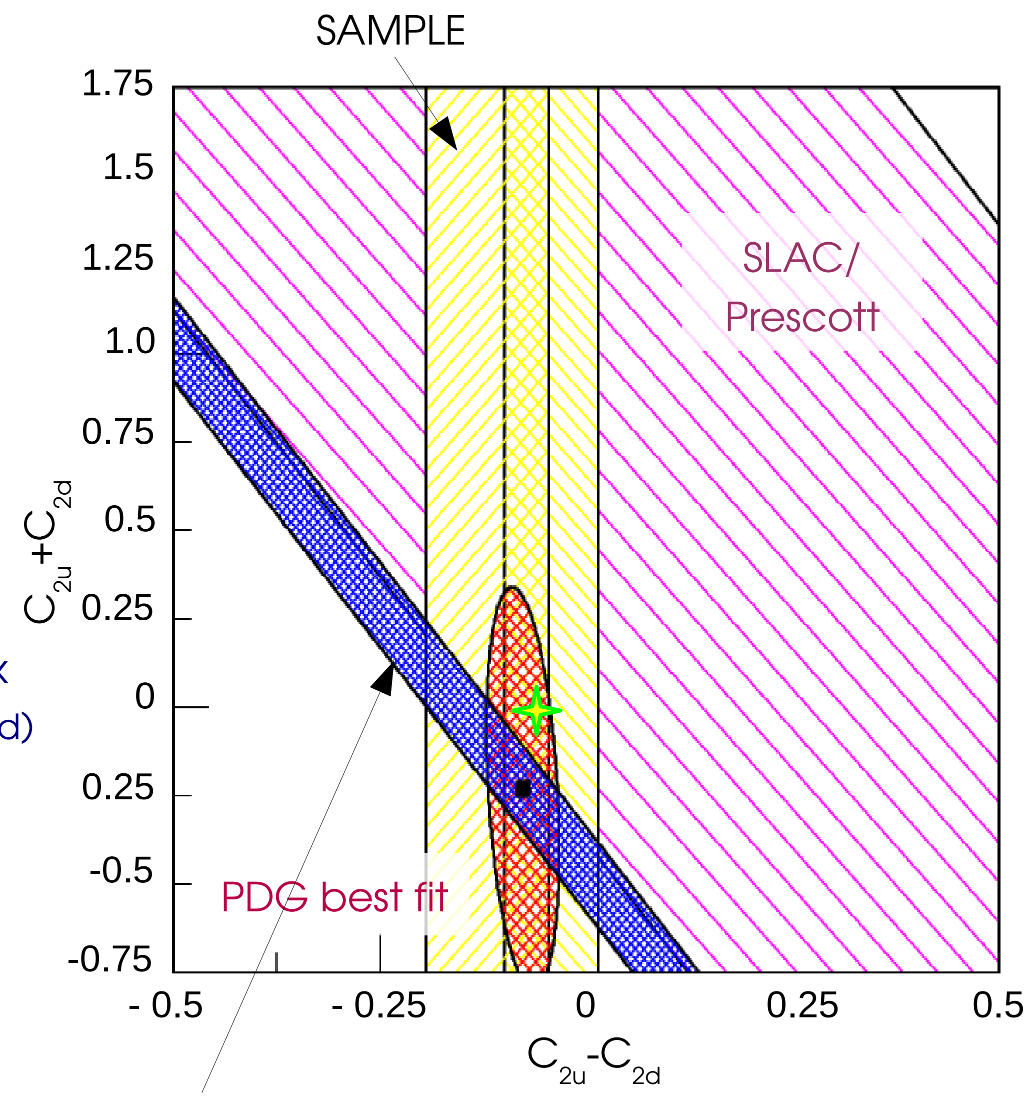


- Best: $\Delta(2C_{2u}-C_{2d}) = 0.24$

The 6 GeV E08-011

all are 1 σ limit





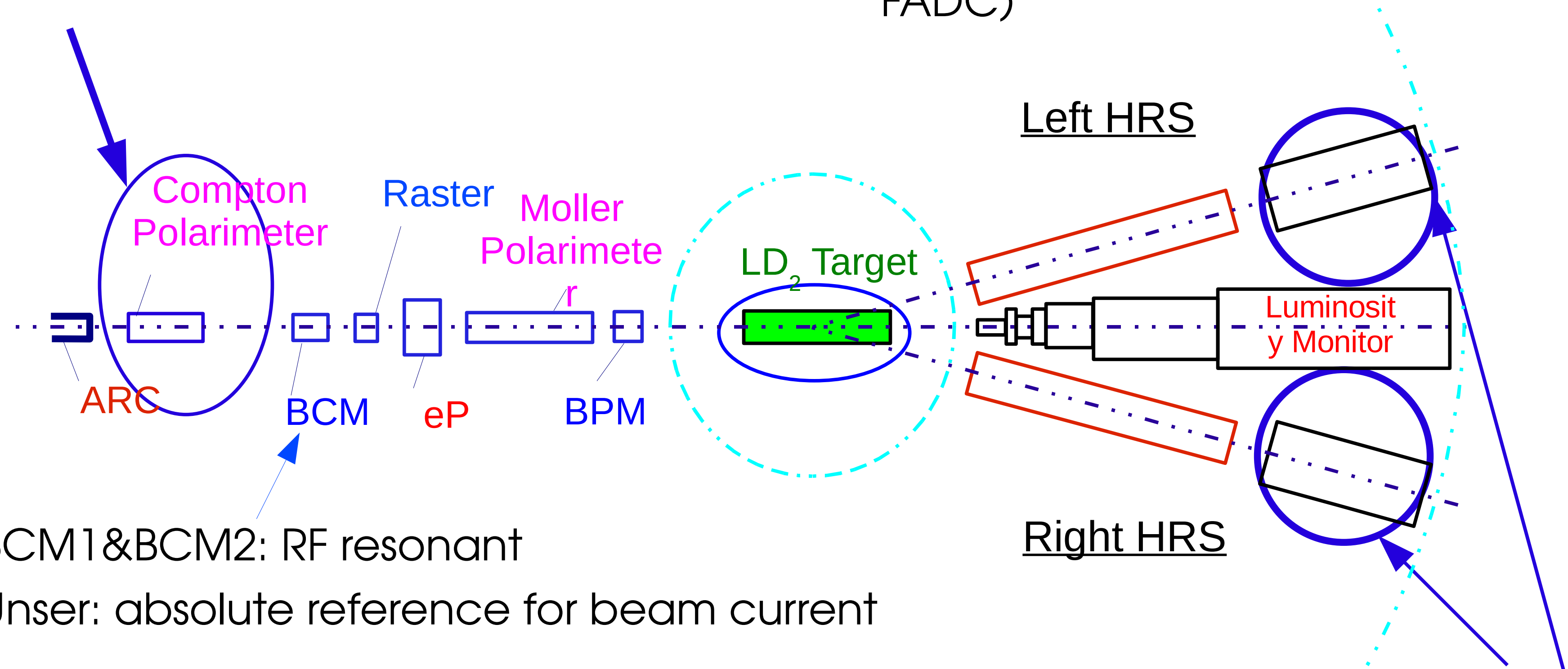
- Best: $\Delta(2C_{2u}-C_{2d}) = 0.24$

Expected: JLab 6 GeV PV-DIS E08-011 (assuming small hadronic effects and a 4% stat error on Ad)

Overview of the Experimental Setup in Hall A

fast-counting DAQ, design goal: 1MHz; (scaler-based, partially w/ FADC)

Expected Precision: 1~2%



BCM1&BCM2: RF resonant

Unser: absolute reference for beam current

- Regular HRS data acquisition (DAQ) count up to 4KHz (expect 500KHz);
- Integration method won't work for DIS;
- Need a new fast-counting DAQ, design goal: 1MHz with on-line particle identification (PID)

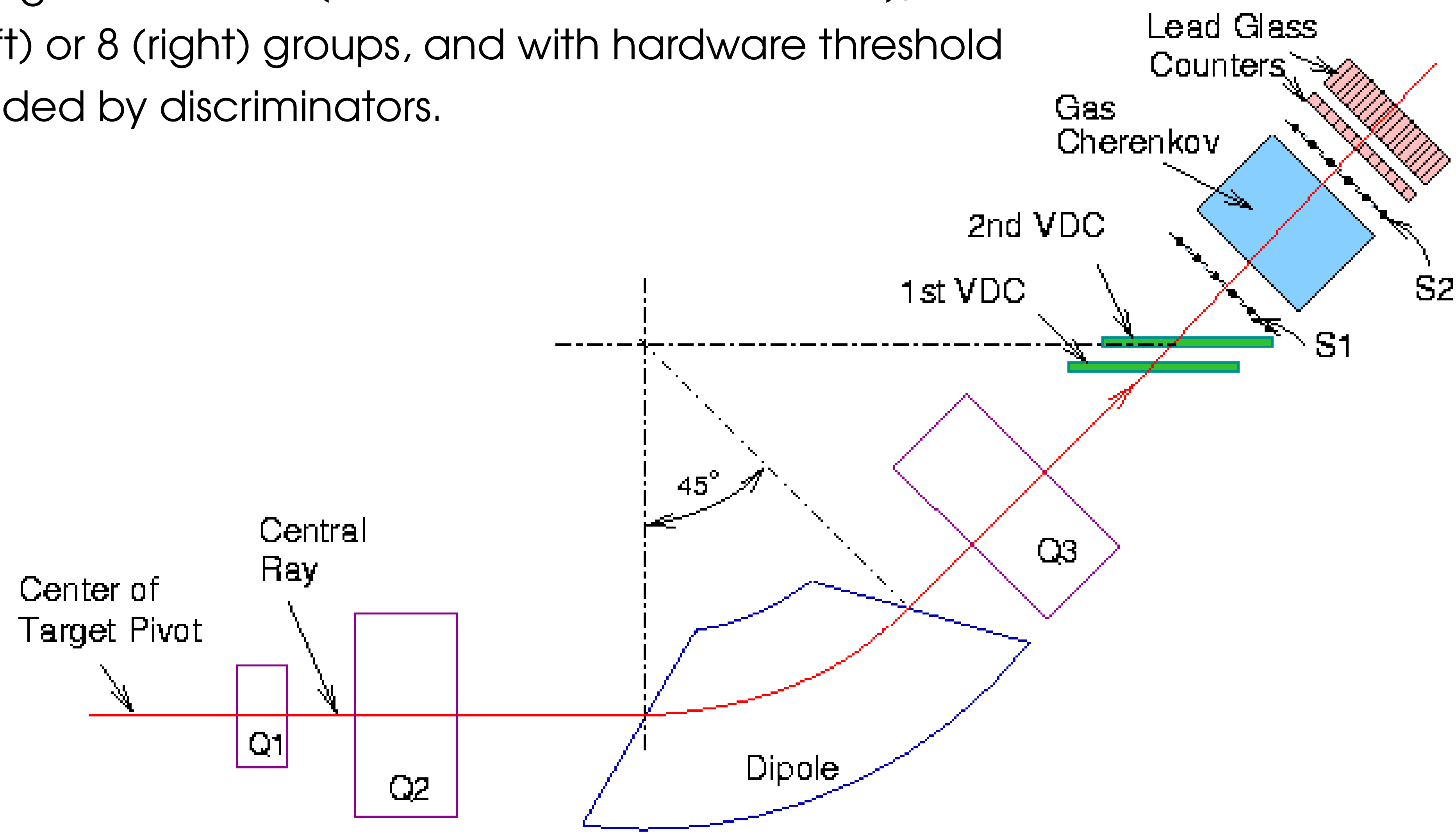
A new fast-counting DAQ

Inputs:

Scintillators ("T1");

Gas cherenkov (GC), with hardware threshold provided by discriminators.

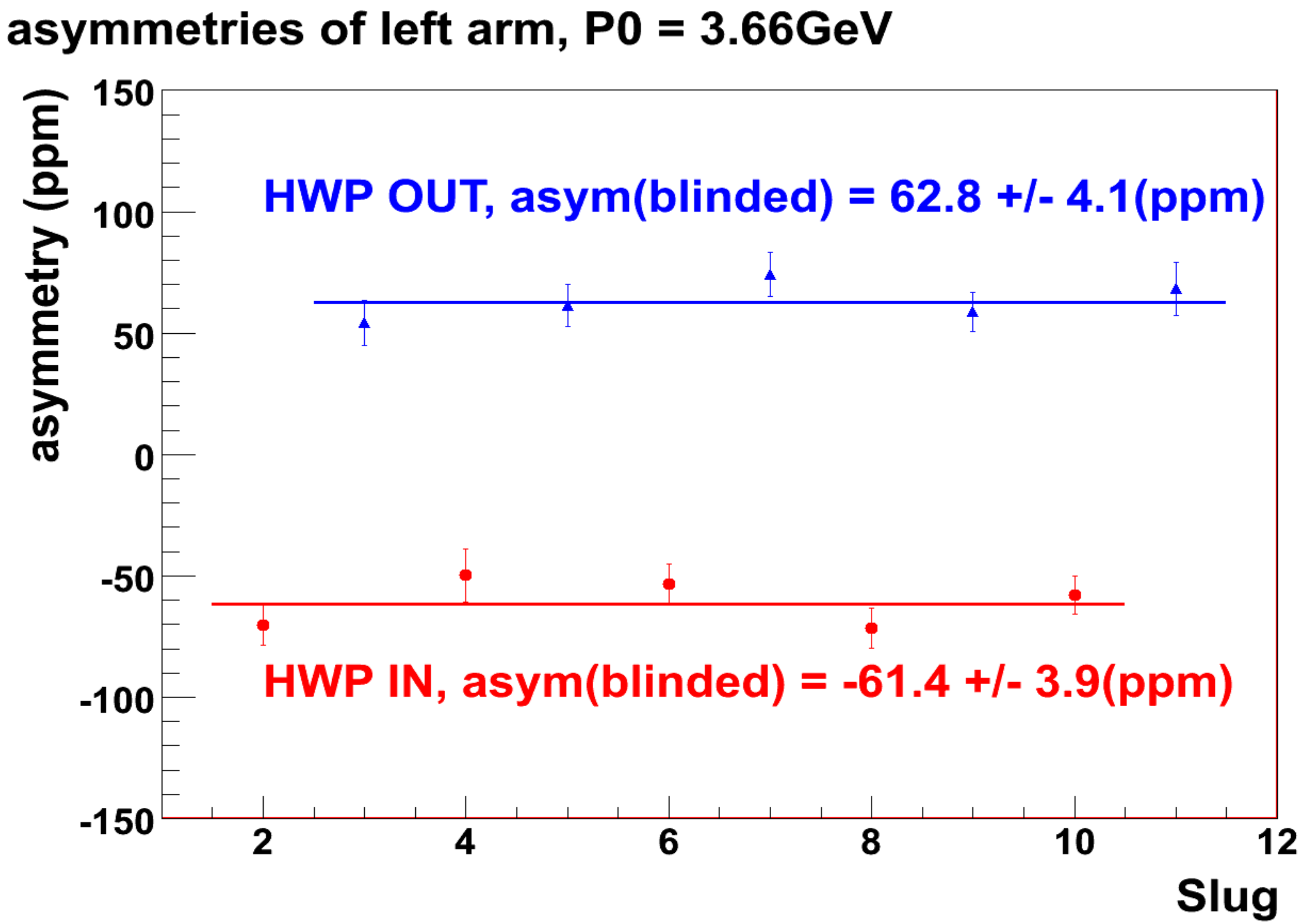
Lead glass counters ("Pre-shower" and "Shower"), divided into 6 (left) or 8 (right) groups, and with hardware threshold provided by discriminators.



PVDIS General Run Information

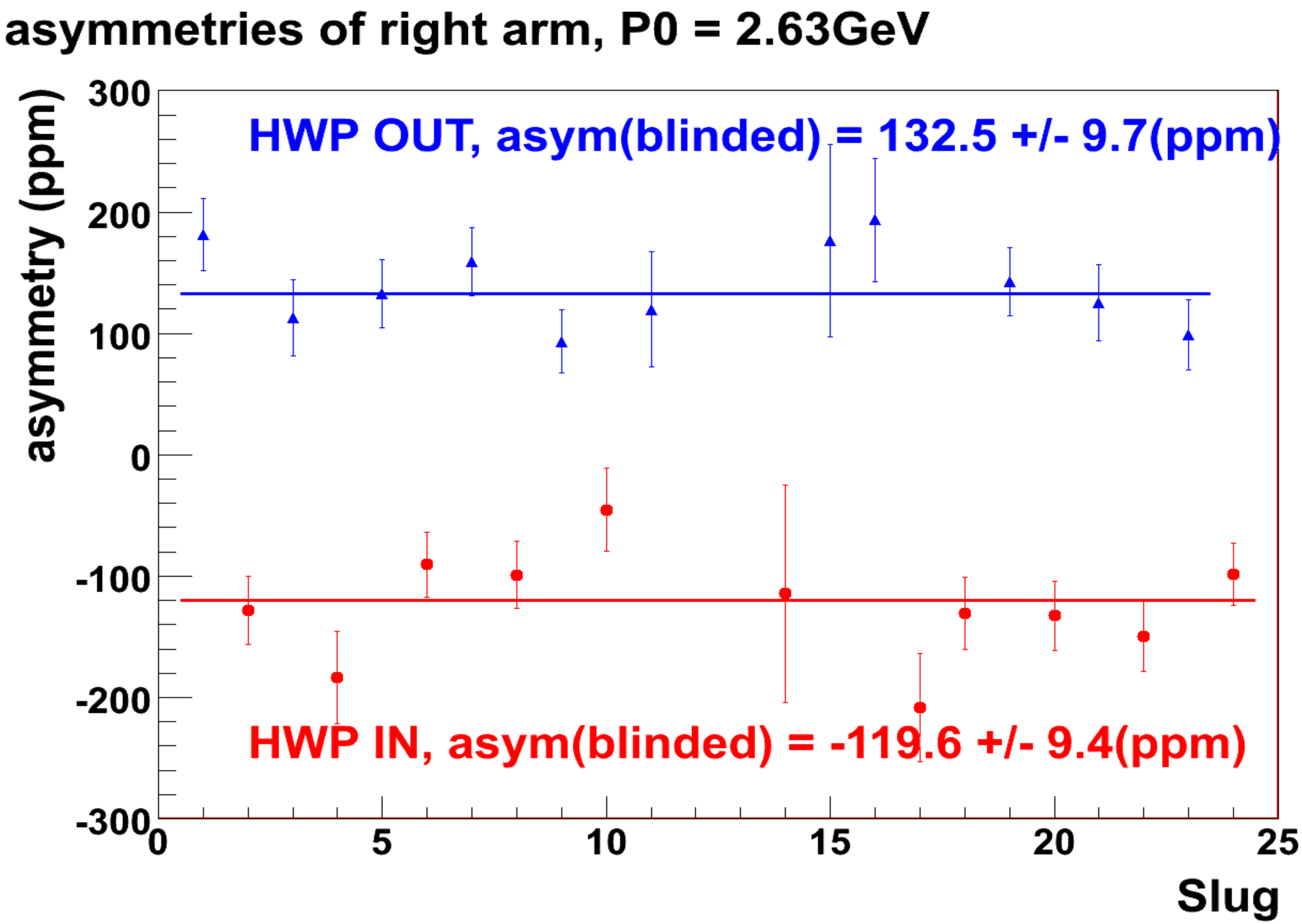
- Beam polarization shared with Hall B and monitored by Moller and Compton (photon-only). Moller results ~87%;
- Beam vertical polarization measured to be <2%;
- Beam charge asymmetry controlled by "parity feedback";
- Target boiling noise monitored by Lumi;
- Beam IHWP switched every 1M helicity pairs (1 pair=66ms) ("slugs");
- Deadtime measurement, analysis in progress;
- Other background or systematics measurements:
  - Pion asymmetries measured continuously by PVDIS DAQ, consistent with zero so far;
  - Al dummy and positive polarity runs (8 hours), rates agree with calculations;
  - Transverse beam polarization running (12 hours), *best DIS transverse measurement so far*, systematic uncertainty under control;
  - Random coincidence measurements.

Online Asymmetries, Q2=1.1, Left Arm Only



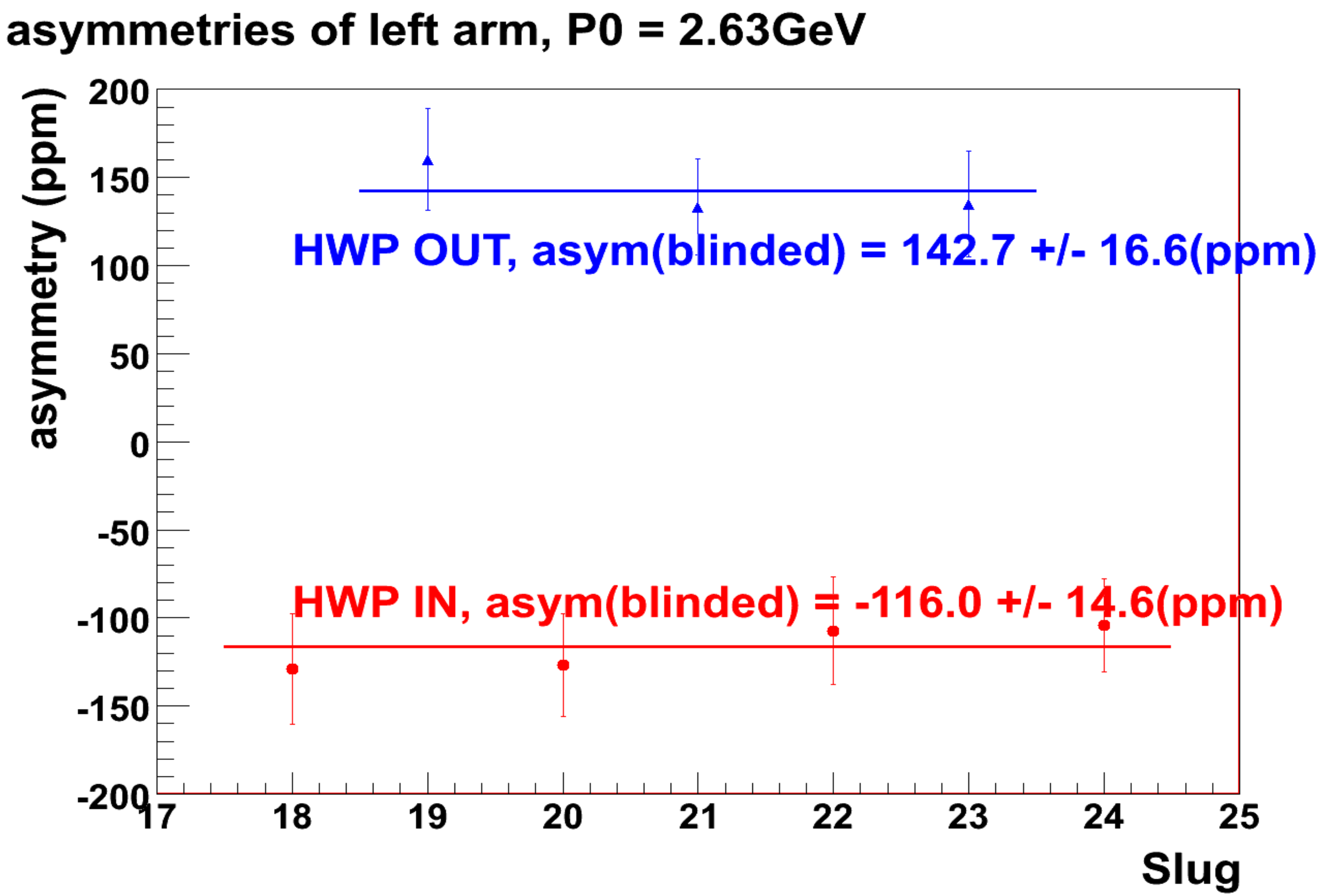
$$Statistical\ Error \approx (4.0/\sqrt{(2)})/91.3 \approx 3.0\,\%$$

Online Asymmetries, Q2=1.9, Right Arm



$$Statistical\ Error \approx (9.6/\sqrt{(2)})/160.7 \approx 4.0\,\%$$

Online Asymmetries, Q2=1.9, Left Arm



Expected Uncertainties on A_d

Source \ $\Delta A_d/A_d$	Q^2=1.1 GeV^2	Q^2=1.9 GeV^2
$\Delta P_b/P_b$=2%	2.0%	2.0%
Deadtime correction	0.3%	0.3%
Target endcap contamination	0.4%	0.4%
Target purity	<0.02%	<0.02%
Pion background	<0.2%	<0.2%
Pair production background	<0.2%	<0.2%
Systematics	2.08%	2.08%
Statistical	3.0%	4.0%
Total	3.7%	4.5%

BCM Calibration

Goal

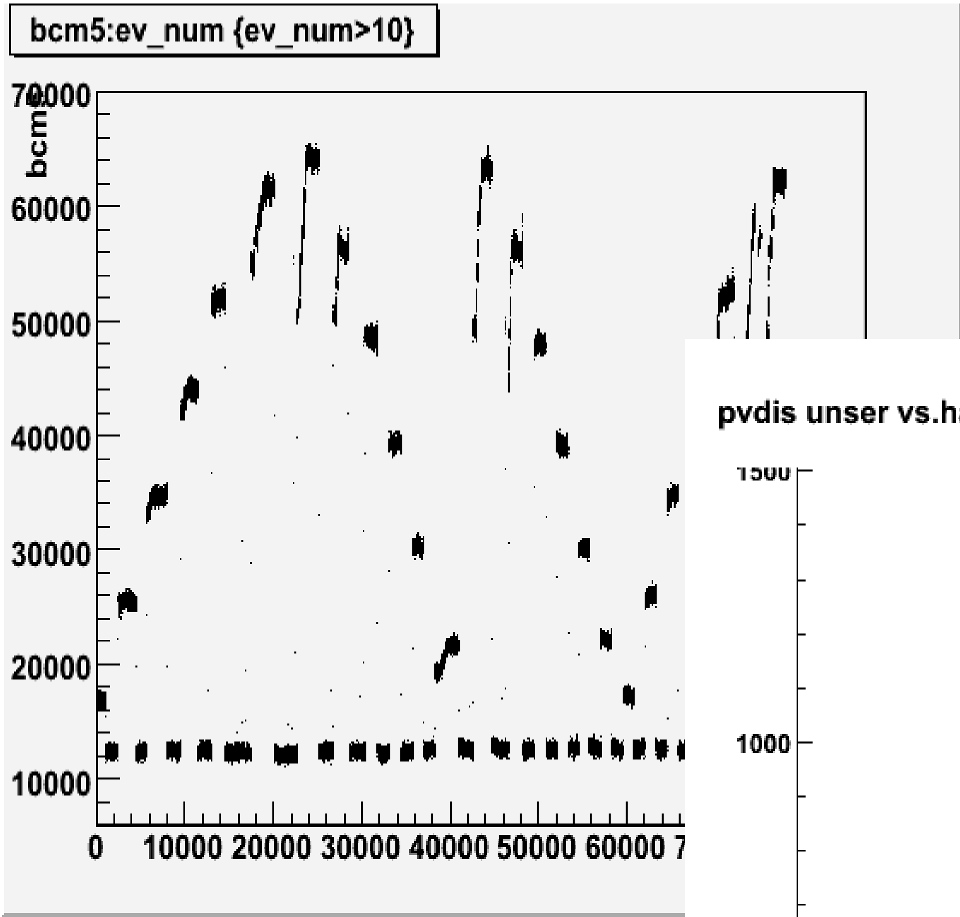
To determine the linearity of BCMs and its effect on the rate-scan method of the deadtime

Background

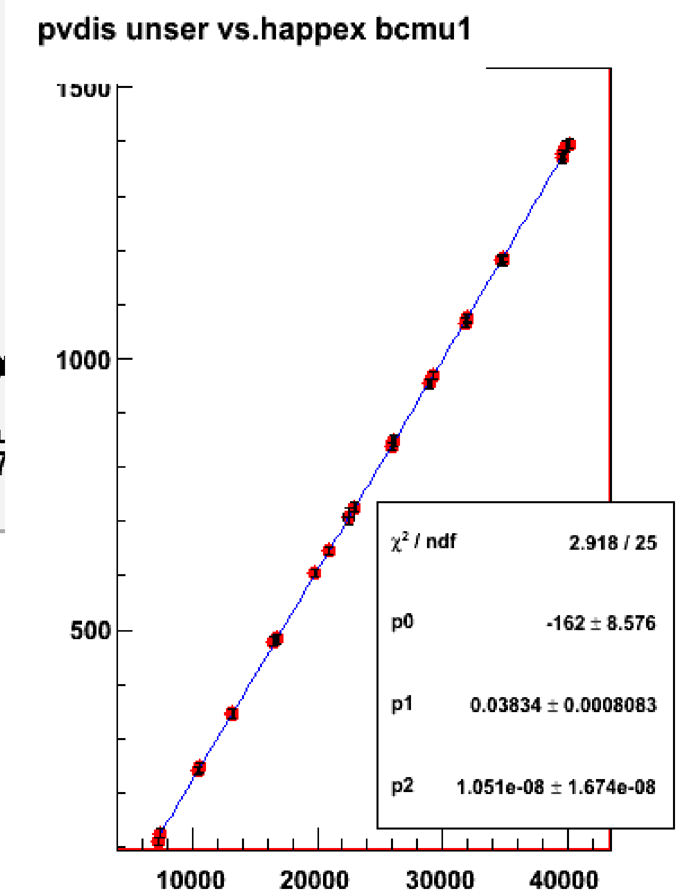
- Beam current measured by two BCMs, 25m upstream of the target
- In between is Unser Monitor which provides an absolute measurement of the current
- Unser Monitor not used for continuous current monitoring, since its output signal drifts during a period of several minutes

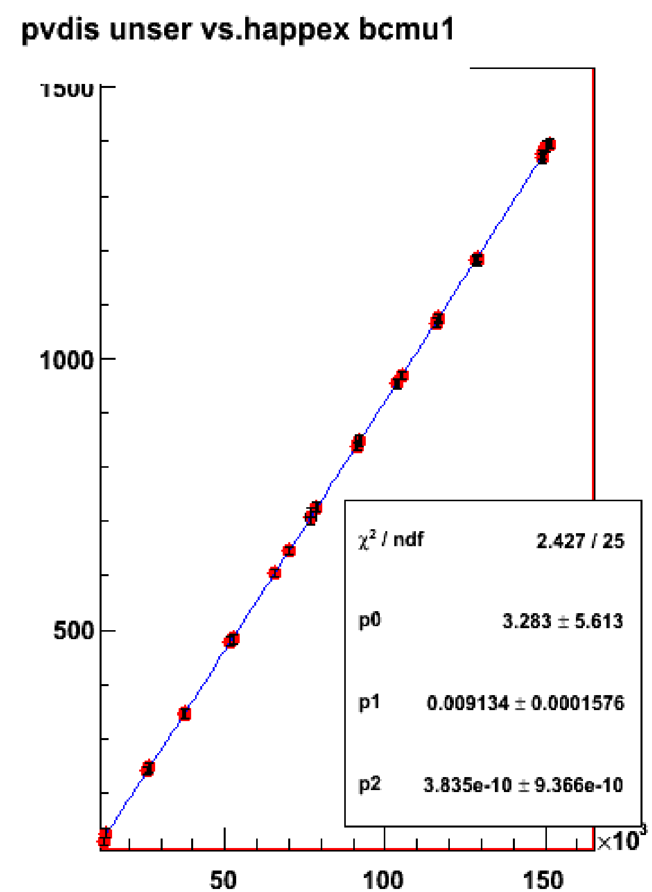
$$I_{unser} = A + B \times BCM + C \times BCM^2$$

BCM Calibration

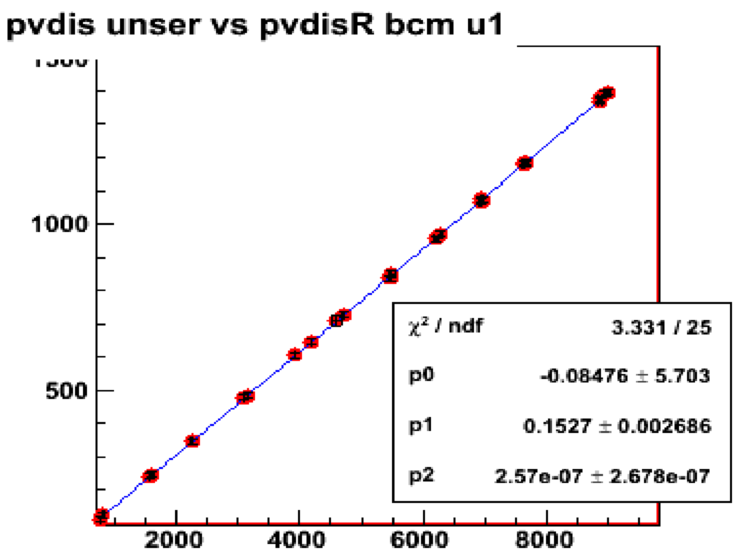


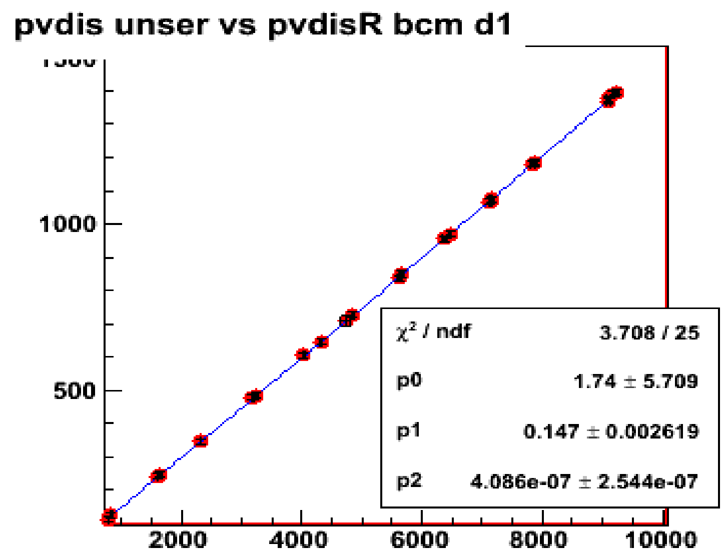
Unser vs time

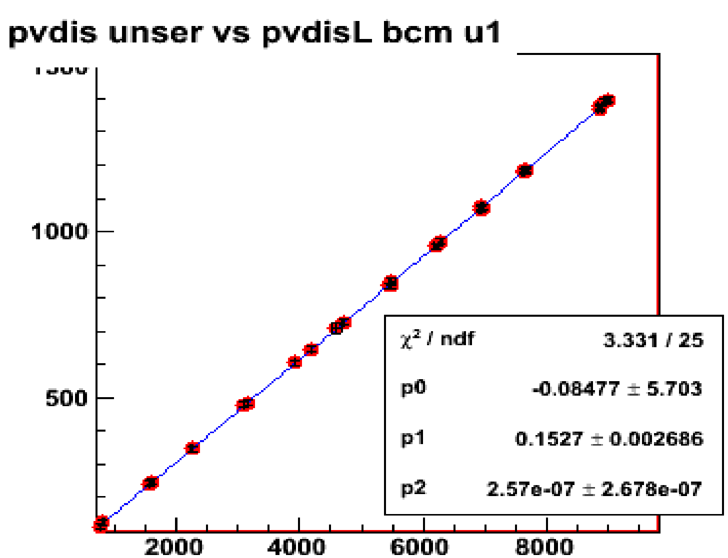


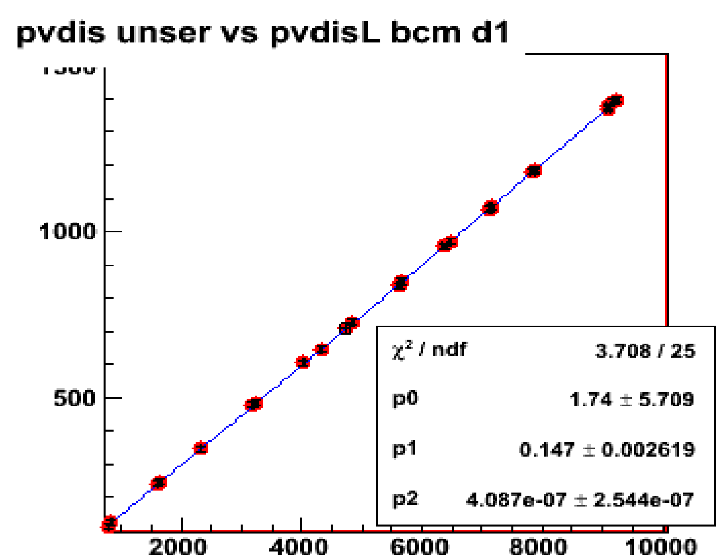


BCM Calibration









Unser vs scaler readings of BCMs in PVDIS DAQ

Deadtime of the Fast-Counting DAQ

- Deadtime measured by multiple methods (goal: 0.3%)
  - Two resolution time (20, 100ns), rate scan
  - "tagger", TDC system

$$A_{PV} = \frac{A_{measured}}{P_b \eta_{DT}}$$

Deadtime of the Fast-Counting DAQ

Rate Scan method to measure the deadtime

Ideally

$$Rate = aI(1 - DT) \qquad DT = aI \times w$$

Where a is a positive constant related to cross section, acceptance and etc. w is deadtime expressed in width.

Then

$$\frac{Rate}{I_{unser}} = a(1 - aw \times I)$$

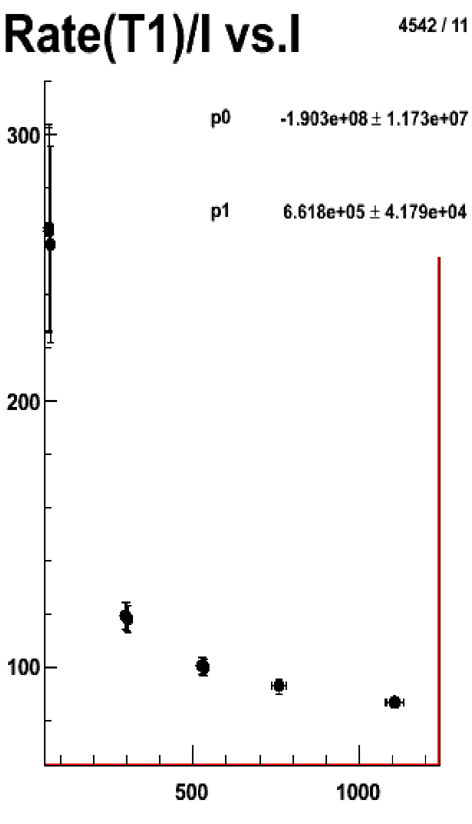
So we can plot Rate/I vs I by using BCM calibration result:

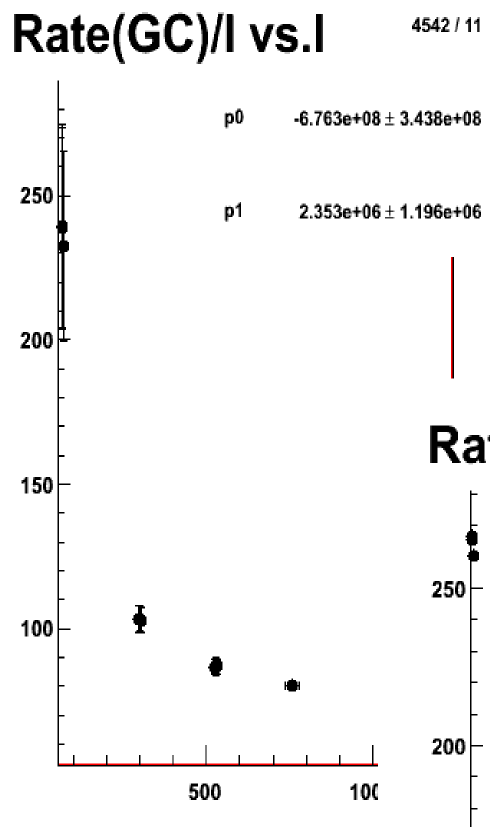
$$I_{unser} = A + B \times BCM + C \times BCM^2$$

ω can be expressed by the fitting results

$$w = -pol1/pol0^2$$

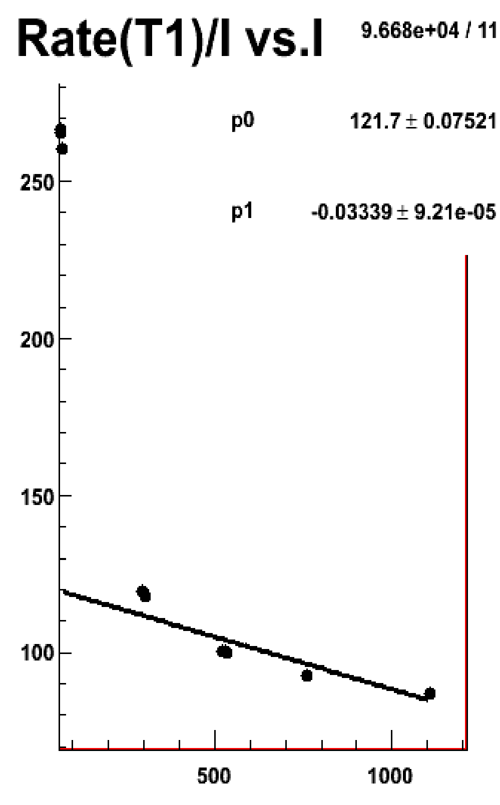
Deadtime of the Fast-Counting DAQ

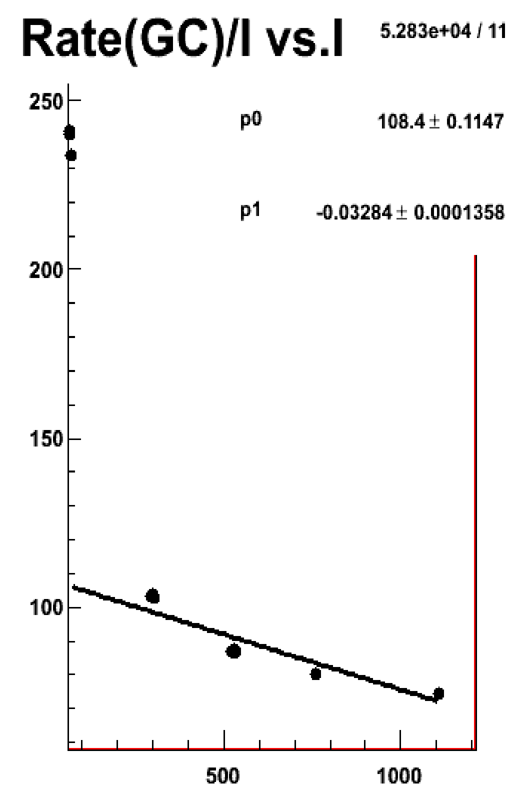




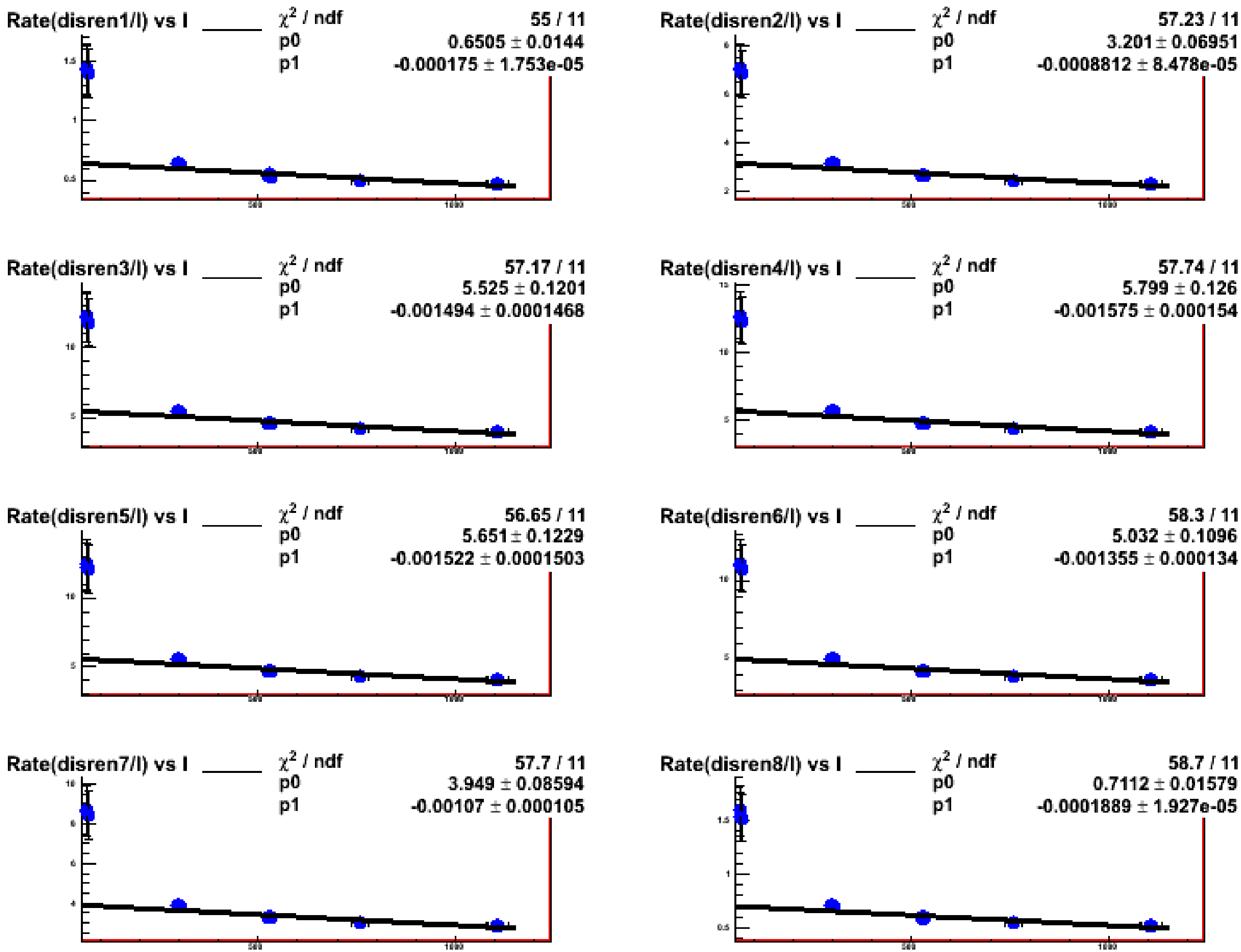
$$\sigma = RMS$$

$$\sigma = RMS/\sqrt{N}$$

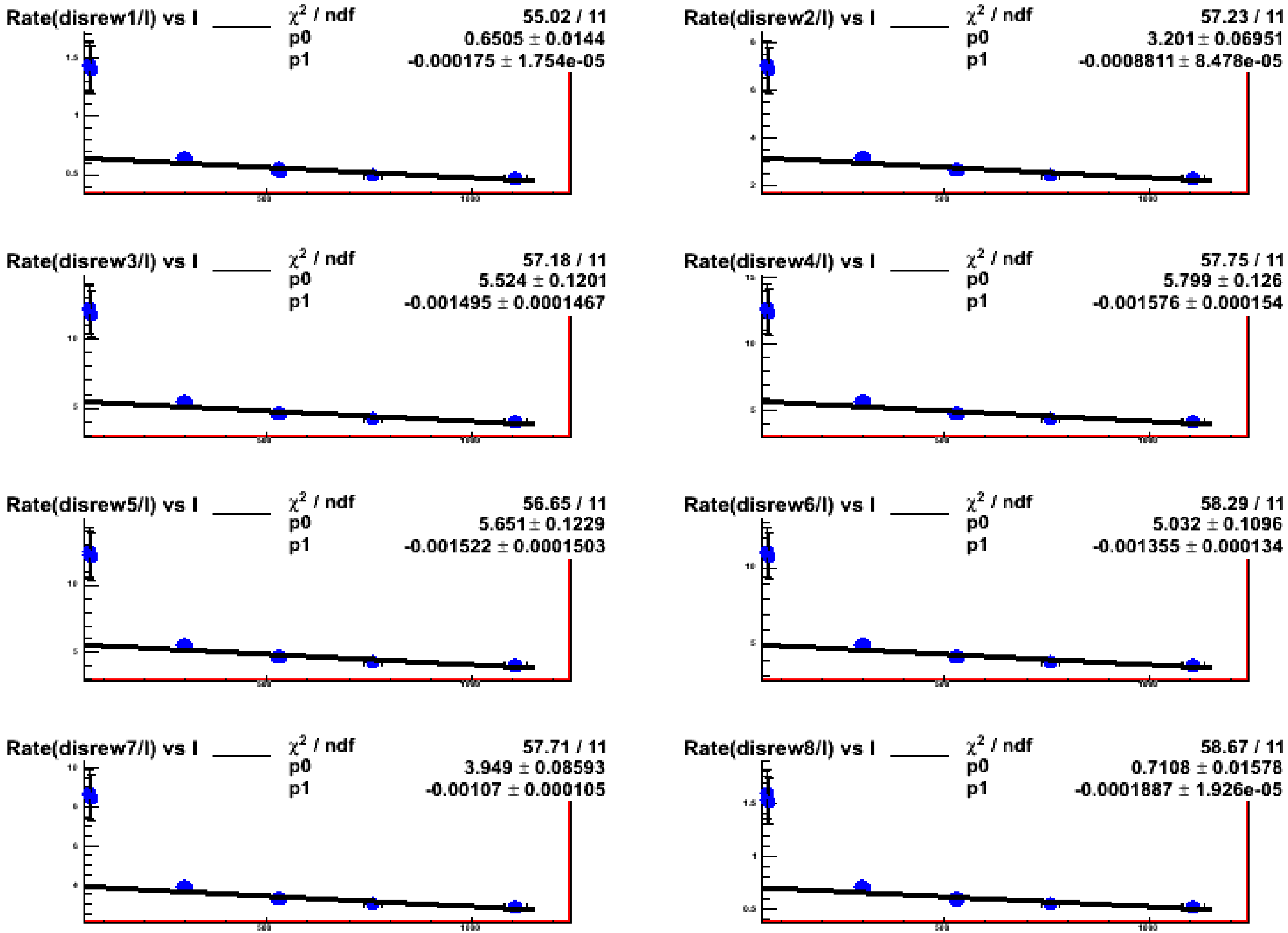




Deadtime of the Fast-Counting DAQ

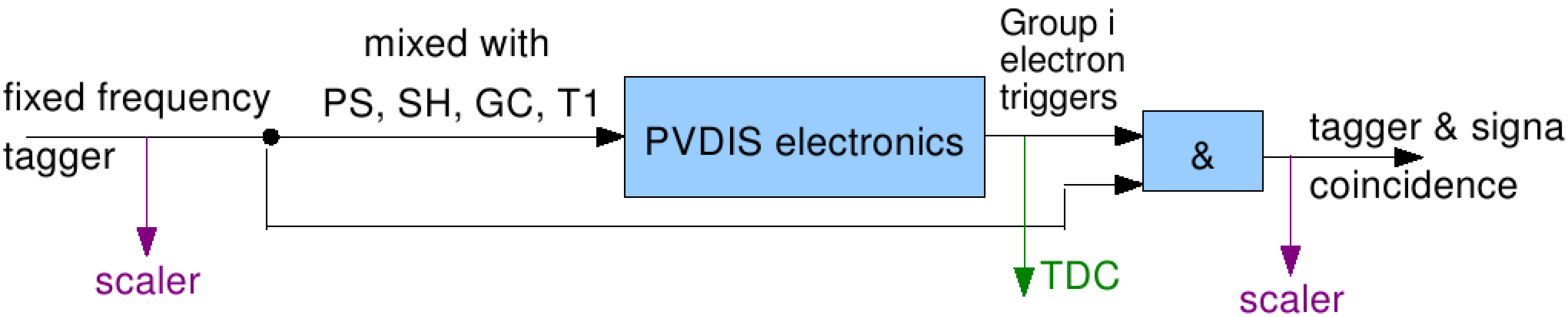


Deadtime of the Fast-Counting DAQ



Deadtime of the Fast-Counting DAQ

The Tagger method to measure deadtime:



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

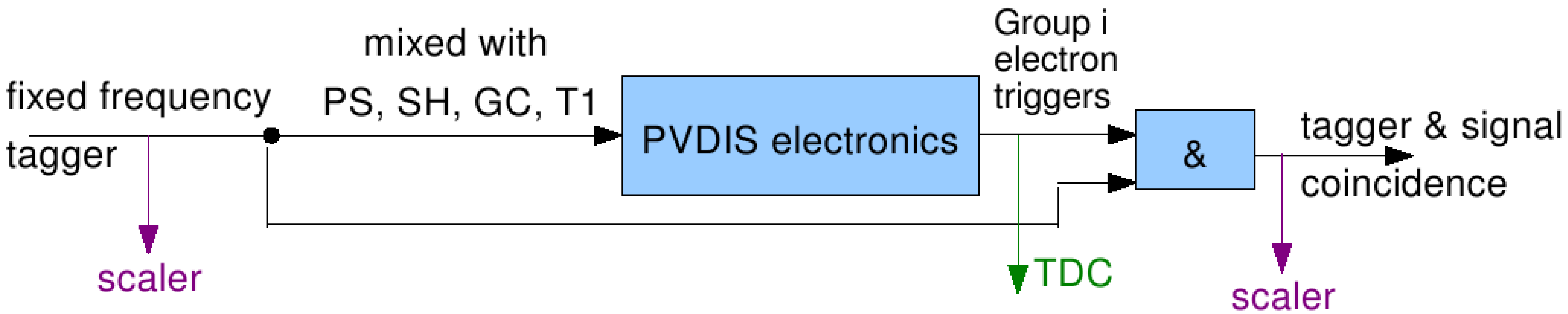
$$\equiv Fractional\ Loss + Pileup$$

Measured by scaler
Different for narrow and wide path

Measured by TDC
Same for narrow and wide path

Deadtime of the Fast-Counting DAQ

The Tagger method to measure deadtime:



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

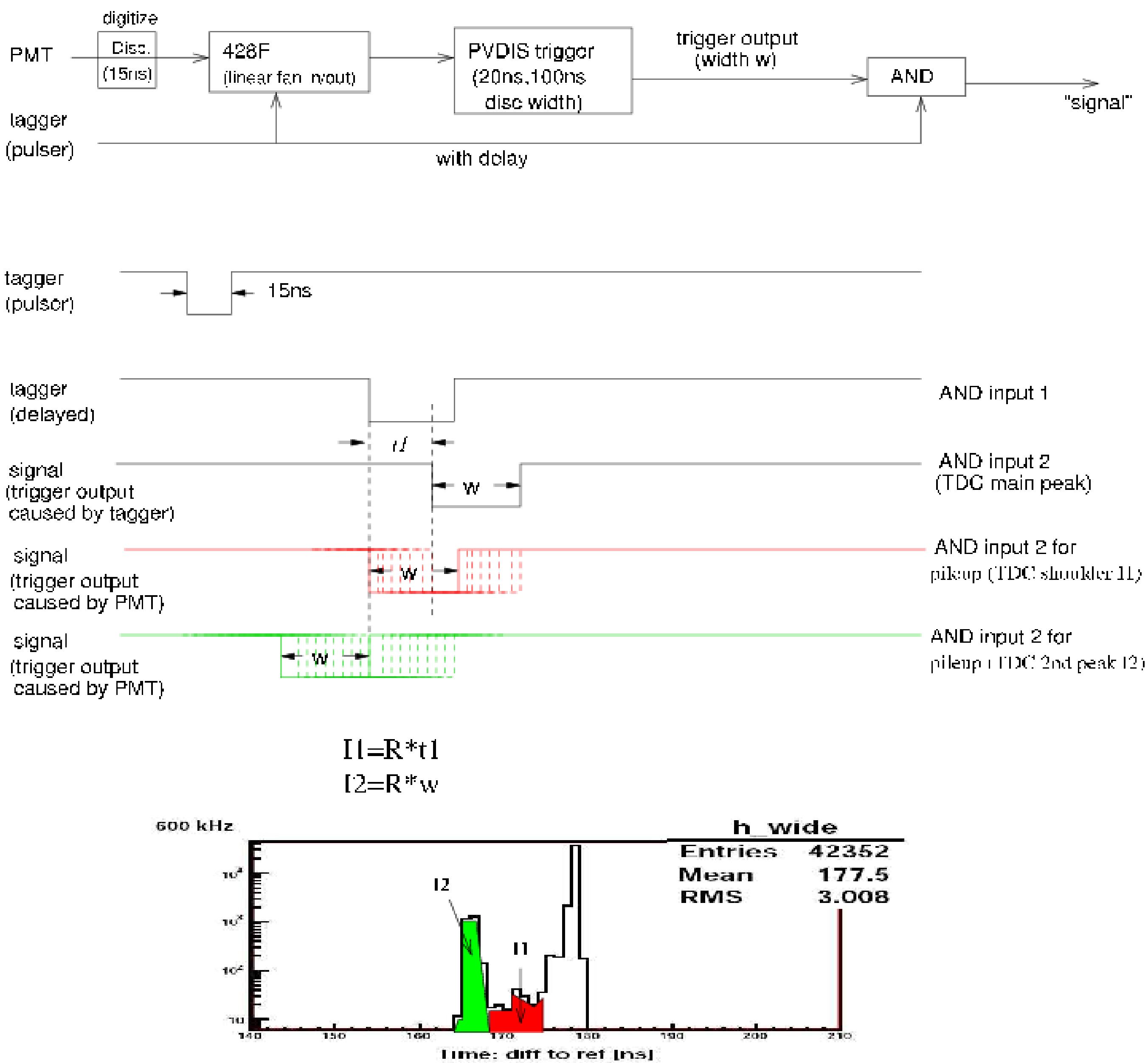
$$\equiv Fractional\ Loss + Pileup$$

In theory: $Deadtime(\%) = Rate \times Width$

Where Width is the widest width through the whole path

- For wide path, width = 100ns
- For narrow path, width = signal width ~ 60ns

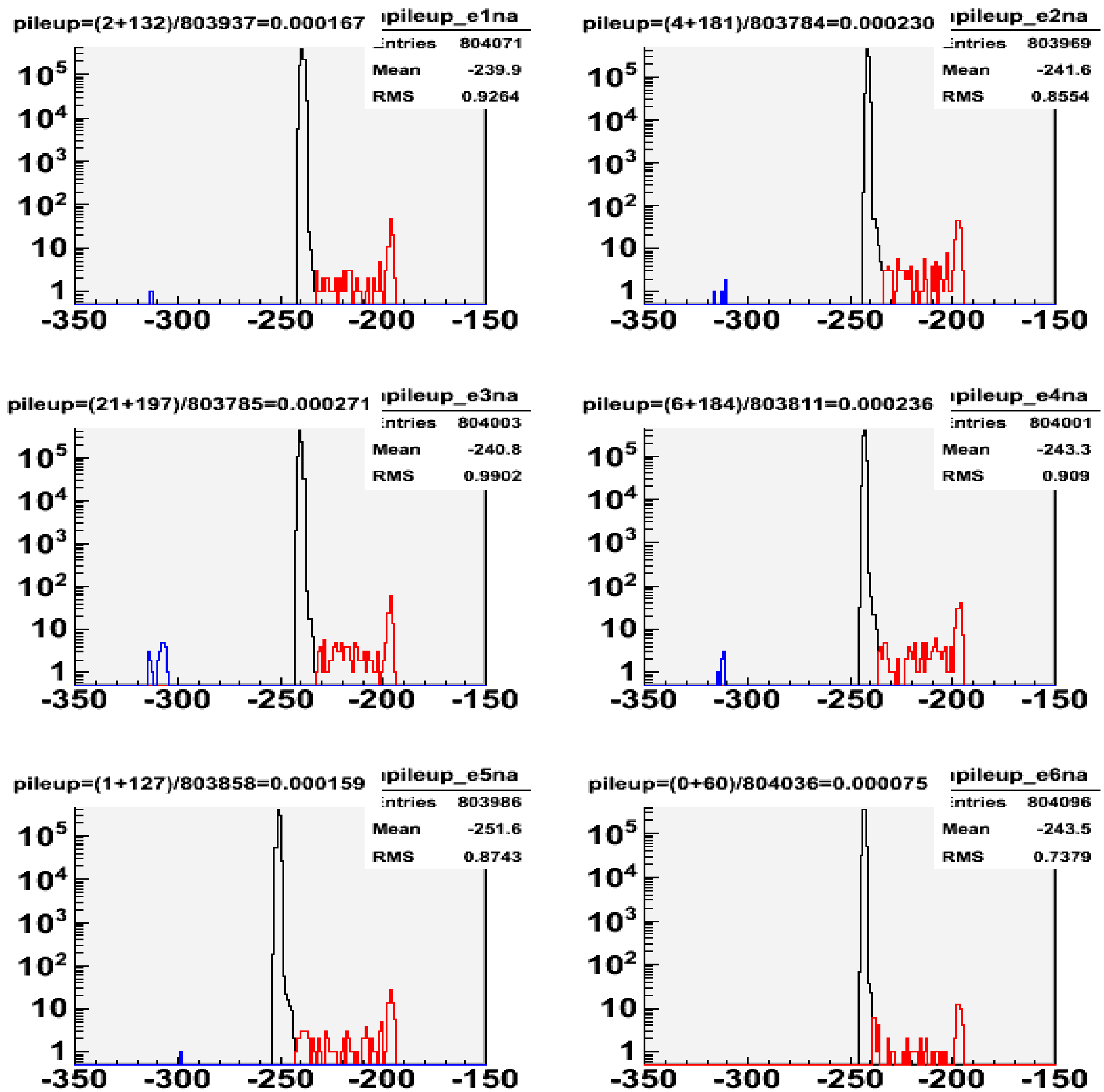
Deadtime of the Fast-Counting DAQ



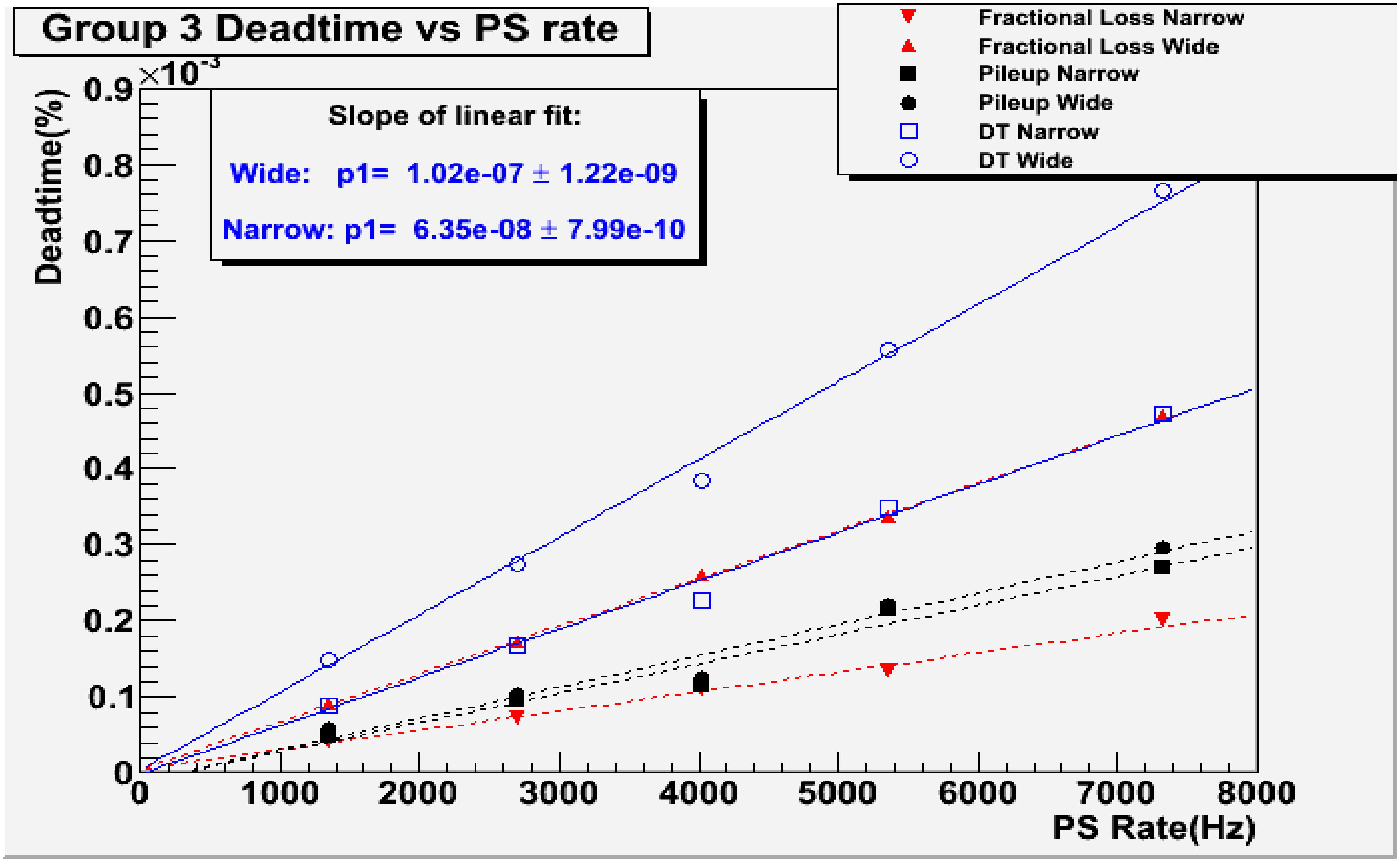
Pileup effect: when the tagger signal follows closely a random PMT signal, the DAQ output caused by the PMT signal would co-incide with the tagger signal, causing a false count that should have lost due to deadtime

TDC Pileup Spectrum

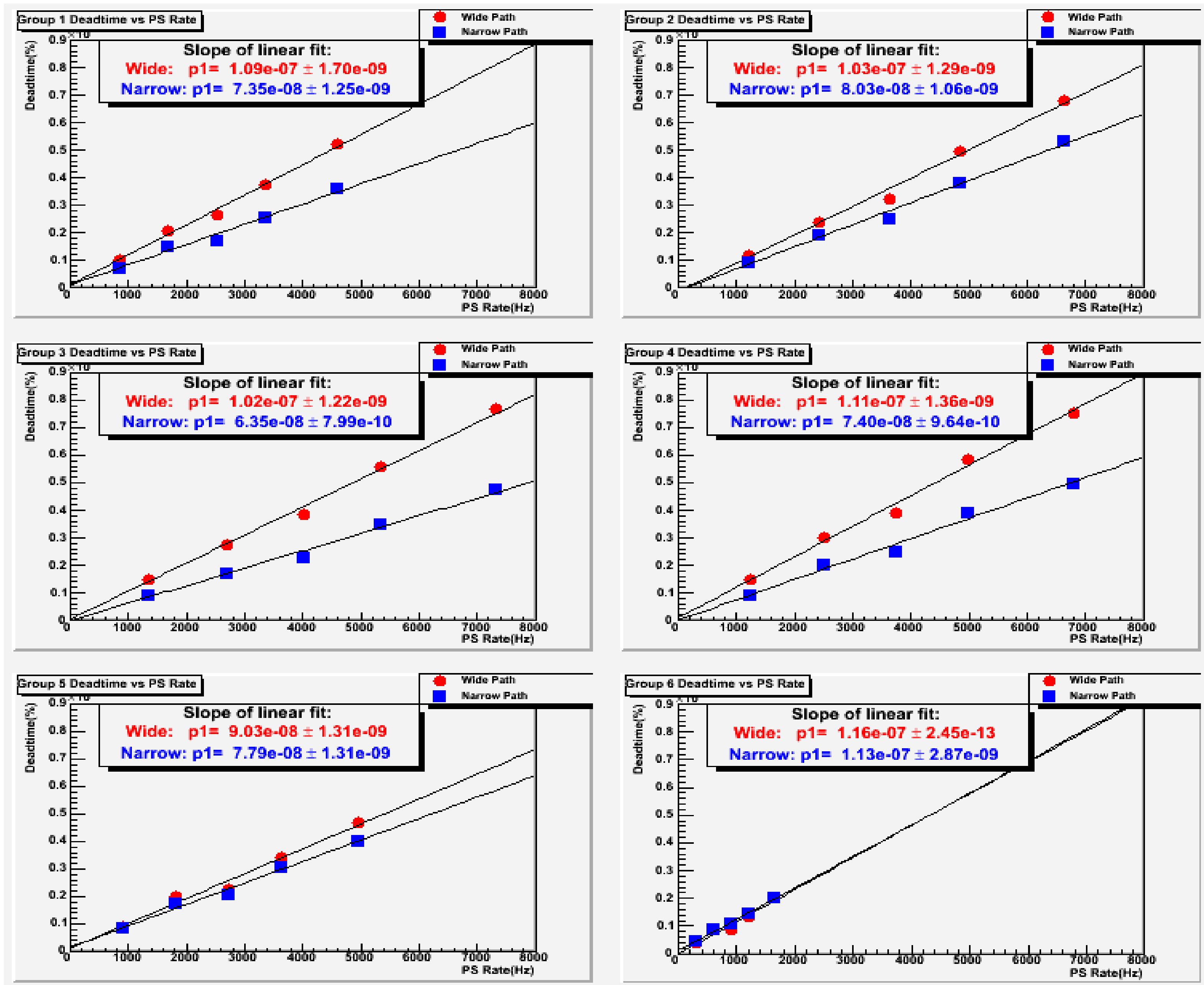
$$Pileup(\%) = \frac{Red + Blue}{Black}$$



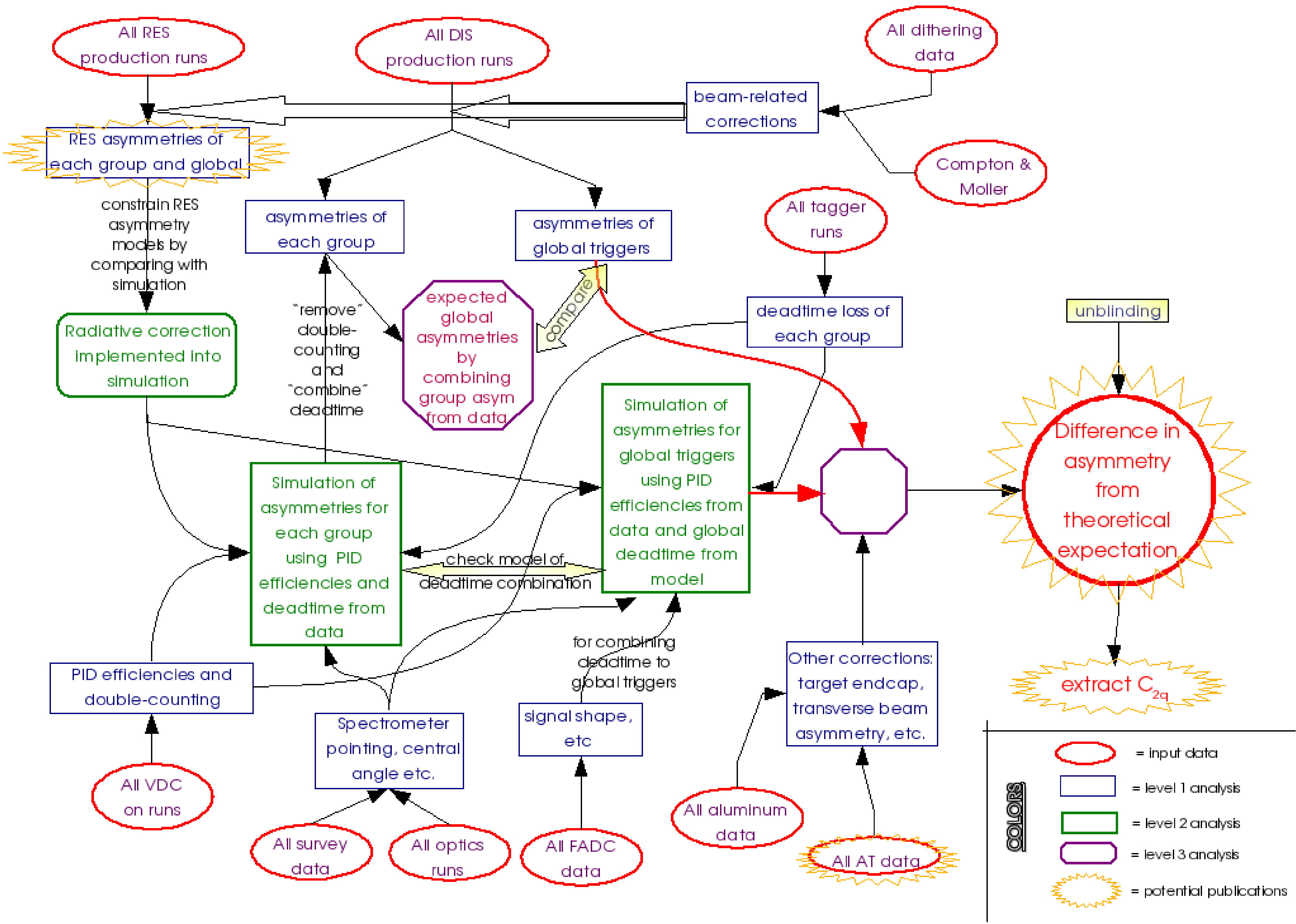
Deadtime Measurement



Deadtime Measurement



E08-011 PVDIS Analysis Flow Chart



Summary

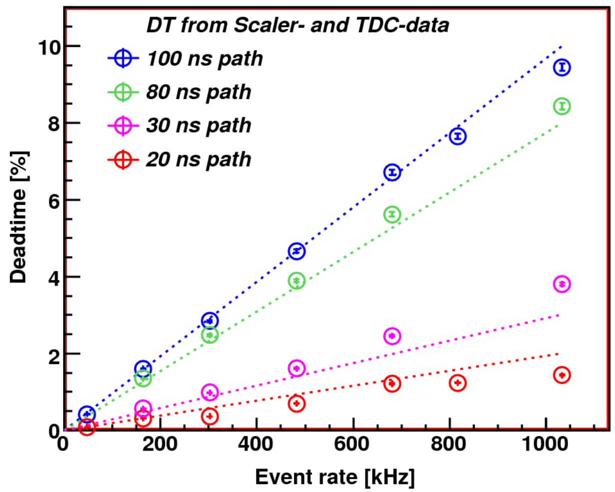
- The Physics of PVDIS

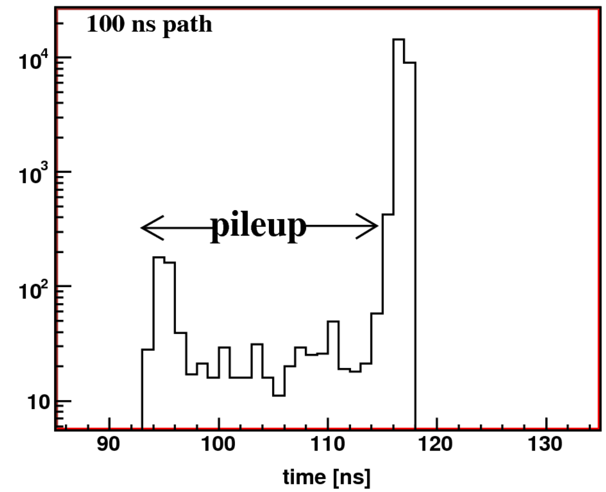
$$A_{pv} \equiv \frac{\sigma^r - \sigma^l}{\sigma^r + \sigma^l} = \frac{(M_\gamma + M_Z^r)^2 - (M_\gamma + M_Z^l)^2}{(M_\gamma + M_Z^r)^2 + (M_\gamma + M_Z^l)^2} \approx \frac{M_Z^r - M_Z^l}{M_\gamma}$$

- Experimental Setup and General Run Information
- Online Results and Expected Uncertainties
- On-Going Data Analysis
  - BCM Calibration ⟶ Need more thinking
  - Deadtime of the Fast-Counting DAQ
- Future Analysis goal

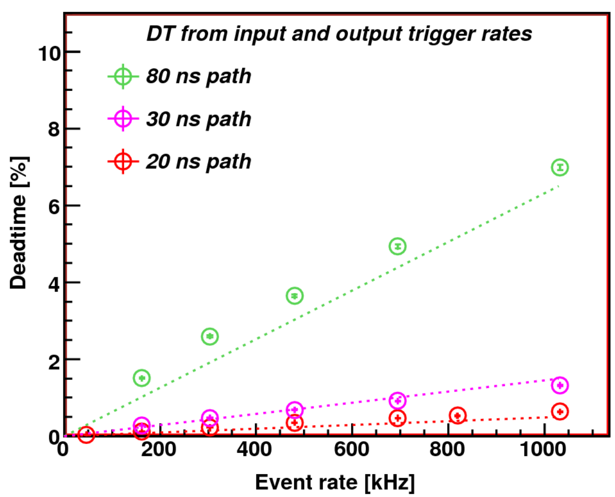
Deadtime measurement:from test and real data

Method I

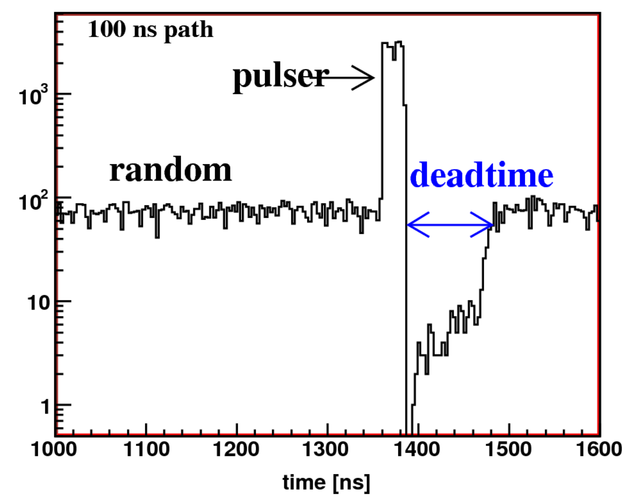




Method II



Method III



Kinematics

Kinematics	I	II
x_{bj}	0.25	0.3
Q^2 $(GeV/c)^2$	1.11	1.9
E_{beam} (GeV)	6.0	6.0
E' (GeV)	3.66	2.63
$\theta(^o)$	12.9°	20.0°
W^2 $(GeV)^2$	4.16	5.30
Y	0.470	0.716
R_C	<0.001	0.001
R_S	0.052	0.041
R_V	0.872	0.910
A_d (measured, ppm)	-91.3	-160.7
e^- rate/HRS (kHz)	269.8	25.1
π^-/e^- ratio	0.9	6.4
e^+/e^- ratio	0.073%	0.463%
Total rate/HRS (kHz)	513.0	186.2