PVDIS at 6 GeV JLab

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- Motivation
- E08-011 at JLab 6 GeV (focus on updates)
- Summary and Outlook

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Electroweak Interaction – The Standard Model

- Weak charged currents given by a $SU(2)_L$ group with weak isospin T;
- The weak neutral current (NC) is obtained by combining the NCs from $SU(2)_L$ and QED ($U^{EM}(1)_\gamma$) :

$$j_\mu^{em} \qquad \qquad J_\mu^3 \longleftarrow \text{completes } SU(2)_L$$

$$J_\mu^{NC} \quad \Leftrightarrow \quad j_\mu^Y \longleftarrow U(1)_Y,\ Y\text{: weak hyper charge}$$

$$Q = T^3 + \frac{Y}{2}$$

observable | theory

$$\text{photon} \longrightarrow A_\mu \qquad \qquad W_\mu^3$$

$$Z^0 \longrightarrow Z_\mu \quad \Leftrightarrow \quad B_\mu$$

Electroweak Interaction – The Standard Model

- Mixing of the $SU(2)_L$ and $U^{EM}(1)_\gamma$ is giving by the Weak Mixing angle θ_W

$$\begin{aligned} A_\mu &= B_\mu \cos\theta_W + W^3_\mu \sin\theta_W && (m=0) \\ Z_\mu &= -B_\mu \sin\theta_W + W^3_\mu \cos\theta_W && (m\neq 0) \end{aligned}$$

- Lepton neutral currents are given by vector and axial couplings

$$J^{NC}_\mu(\nu) = \frac{1}{2}\left(\bar{u}_\nu \gamma_\mu \frac{1}{2}(1-\gamma^5) u_\nu\right)$$

$$J^{NC}_\mu(q) = \left(\bar{u}_q \gamma_\mu \frac{1}{2}(c^q_V - c^q_A \gamma^5) u_q\right)$$

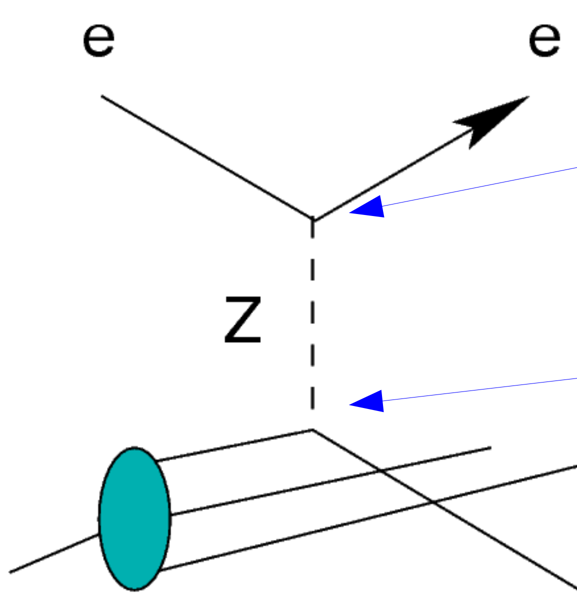
In the Standard Model

fermions	c^f_A	c^f_V
ν_e, ν_μ	$\frac{1}{2}$	$\frac{1}{2}$
e-, μ-	$-\frac{1}{2}$	$-\frac{1}{2}+2\sin^2\theta_W$
u, c	$\frac{1}{2}$	$\frac{1}{2} - \frac{4}{3}\sin^2\theta_W$
d, s	$-\frac{1}{2}$	$-\frac{1}{2}+\frac{2}{3}\sin^2\theta_W$

Neutral Weak Couplings from Charged Lepton Scattering

- Asymmetries in charged lepton-nucleon scattering can be used to measure $c^e_{V,A}\, c^q_{V,A}$
- In Deep Inelastic Scattering, sensitive to the nucleon partonic structure (different from elastic scatterings)

$$L^{\text{lepton scatt.}}_{NC} = \sum_q \left[c^l_A c^q_V \bar{l}\gamma^\mu \gamma_5 l\, \bar{q}\gamma_\mu q + c^l_V c^q_A \bar{l}\gamma^\mu l\, \bar{q}\gamma_\mu \gamma_5 q + c^l_A c^q_A \bar{l}\gamma^\mu \gamma_5 l\, \bar{q}\gamma_\mu \gamma_5 q \right]$$



$$J^{NC}_\mu(e) = \left(\bar{u}_e \gamma_\mu \frac{1}{2}(c^e_V - c^e_A \gamma^5) u_e \right)$$

$$J^{NC}_\mu(q) = \left(\bar{u}_q \gamma_\mu \frac{1}{2}(c^q_V - c^q_A \gamma^5) u_q \right)$$

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C_{1q} $\quad$ C_{2q} $\quad$ C_{3q}

parity-violating

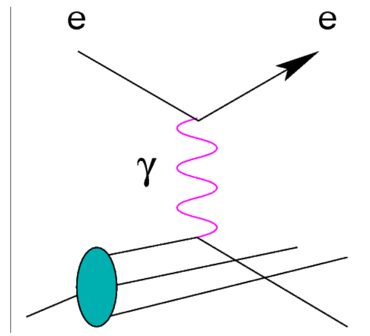
e_L, e_R cross sections

lepton charge conjugate-violating

e_L, e^+_R cross sections

PVDIS Asymmetries

$A_{PV} =$



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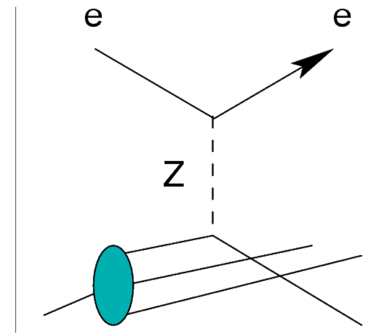


- Deuterium:

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

$C_{1q} = g_A^e g_V^q \qquad C_{2q} = g_V^e g_A^q$ — neutral weak couplings

$R_{V,S,C}(x)$ — parton distribution functions

- PVDIS has the potential to explore both electro-weak and hadronic physics (higher-twist, charge symmetry violation, etc.)
- First, exploratory step: E08-011at JLab 6 GeV
- Larger program at 11 GeV, *see next talk by P. Souder*

JLab 6 GeV Experiment 08-011

Co-spokespeople: X. Zheng, P.E. Reimer, R. Michaels

Postdoc: Ramesh Subedi(UVa);

Grad. students: Xiaoyan Deng (UVa), Kai Pan (MIT), Diancheng Wang (UVa)

(Hall-A Collaboration Experiment, previously E05-007, re-approved by PAC33 for 32 days, rated A-)

- Use 85μA, 6 GeV, 80% polarized beam on a 25-cm LD2 target;
- Two Hall A High Resolution Spectrometers detect scattered electrons;
- Measure PV asymmetry A_d at Q^2=1.10 and 1.90 GeV^2 to 2.7% (stat.);
  - A_d at Q^2=1.10 will investigate the size of higher twist effects;
  - If HT is small, can extract $2C_{2u}$-C_{2d} from A_d at Q^2=1.90 to ±0.04 (or with reduced precision if higher twists are un-expectedly large)
- Schedule to run Nov-Dec. 2009, after HAPPEX-III, and before PREX.

The Collaboration

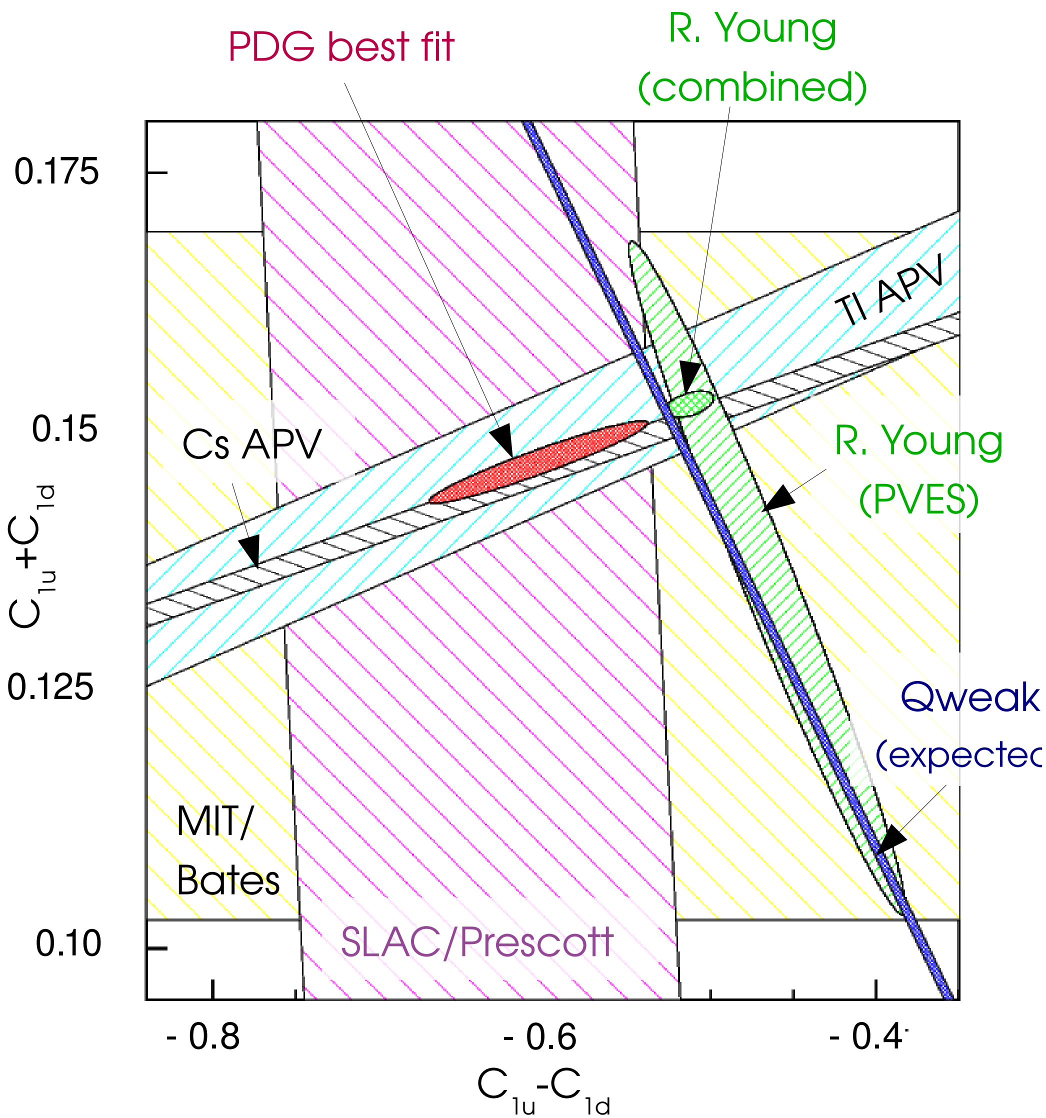
A. Afanasev, D.S. Armstrong, J. Arrington, T.D. Averett, E.J. Beise, W. Bertozzi, P.E. Bosted, J.R. Calarco, G.D. Cates, J.-P. Chen, E. Chudakov, P. Decowski, X.-Y. Deng, A. Deur, J. Erler, R. Feuerbach, J.M. Finn, S. Gilad, R. Gilman, C. Glashausser, K.A. Griffioen, K. Hafidi, J.-O. Hansen, R. Holmes, R.J. Holt, T. Holmstrom, H.E. Jackson, X. Jiang, W. Korsch, K. Kumar, N. Liyanage, D.J. Mack, D.J. Margoziotis, P. Markowitz, R. Michaels, P. Monaghan, V. Nelyubin, K. Pan, K. Paschke, D.H. Potterveld, A.J. Puckett, Y. Qiang, R. Ransome, P.E. Reimer, B. Reitz, E.C. Schulte, J. Singh, S. Sirca, R. Snyder, P. Souder, R. Subedi, V. Sulkosky, W.A. Tobias, D.-C. Wang, B. Zeidman, X. Zhan, X. Zheng

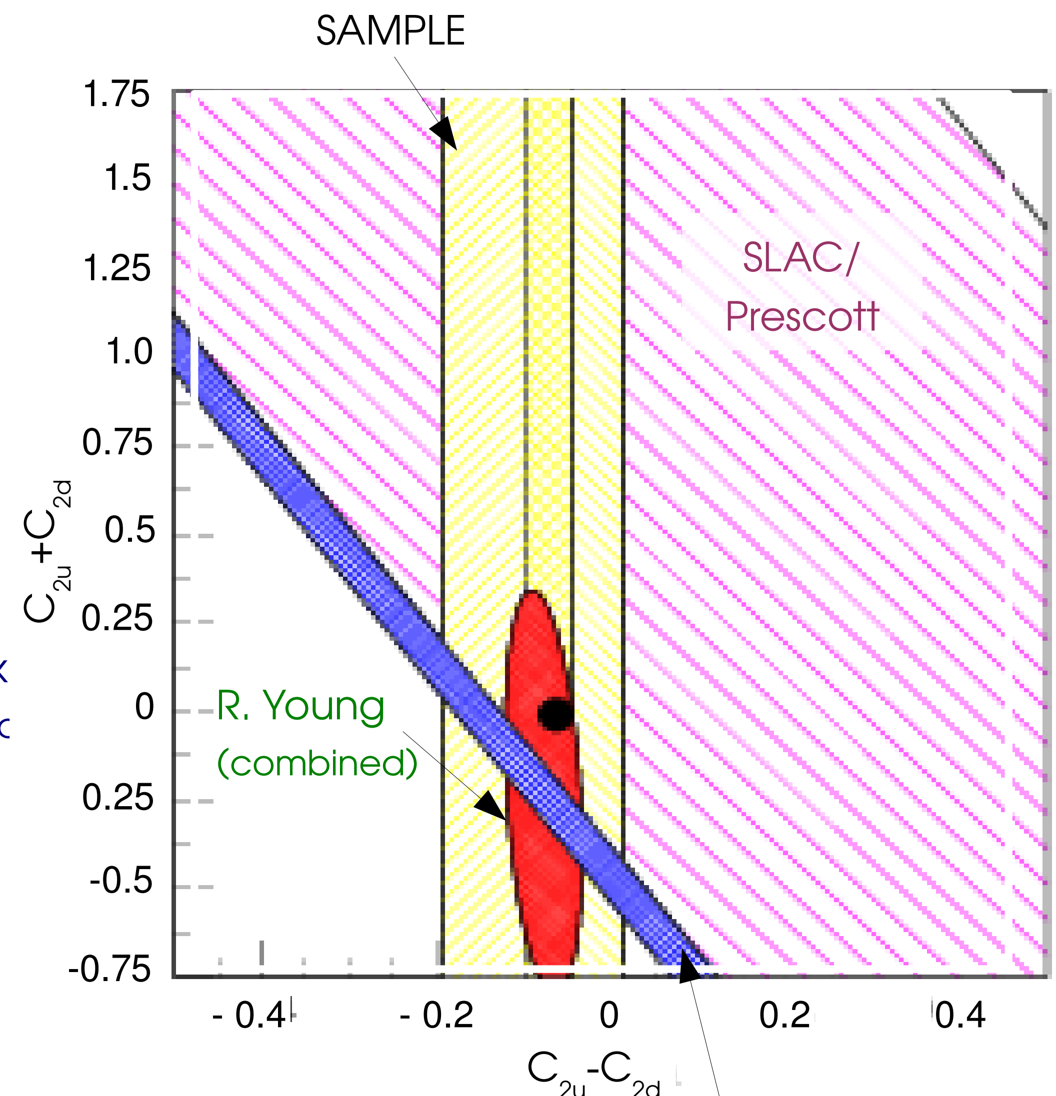
The Hall A Collaboration

ANL, Calstate, FIU, Jlab, Kentucky, U. of Ljubljana (Slovenia), MIT, UMD, Umass, UNH, Universidad Nacional Autonoma de Mexico, Rutgers, Smith C., Syracuse, Uva, W&M

The 6 GeV E08-011

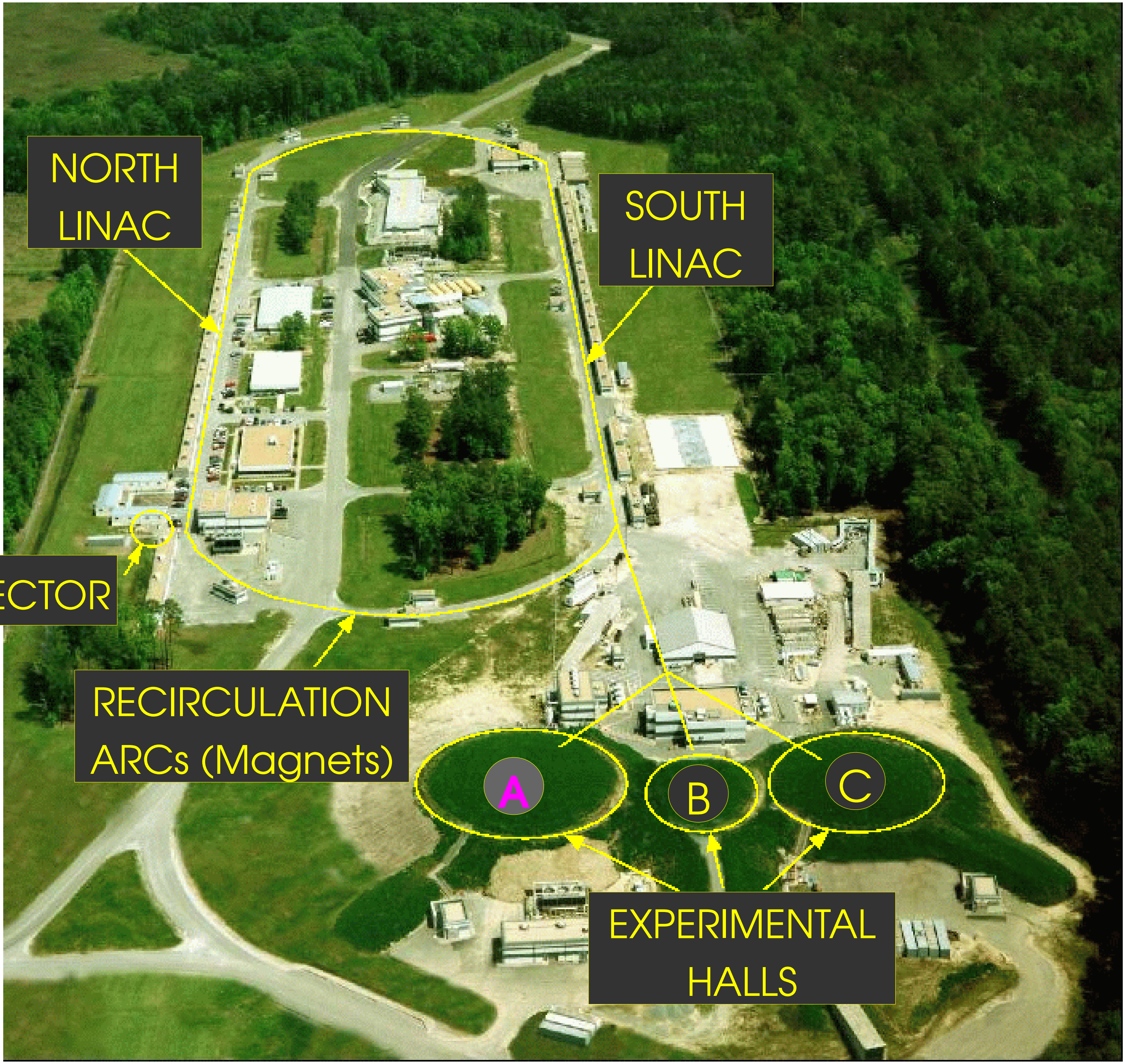
all are 1 σ limit





Expected: JLab 6 GeV PV-DIS E08-011
(assuming small hadronic effects)

The Accelerator at Jefferson Lab, Virginia, USA



Challenges

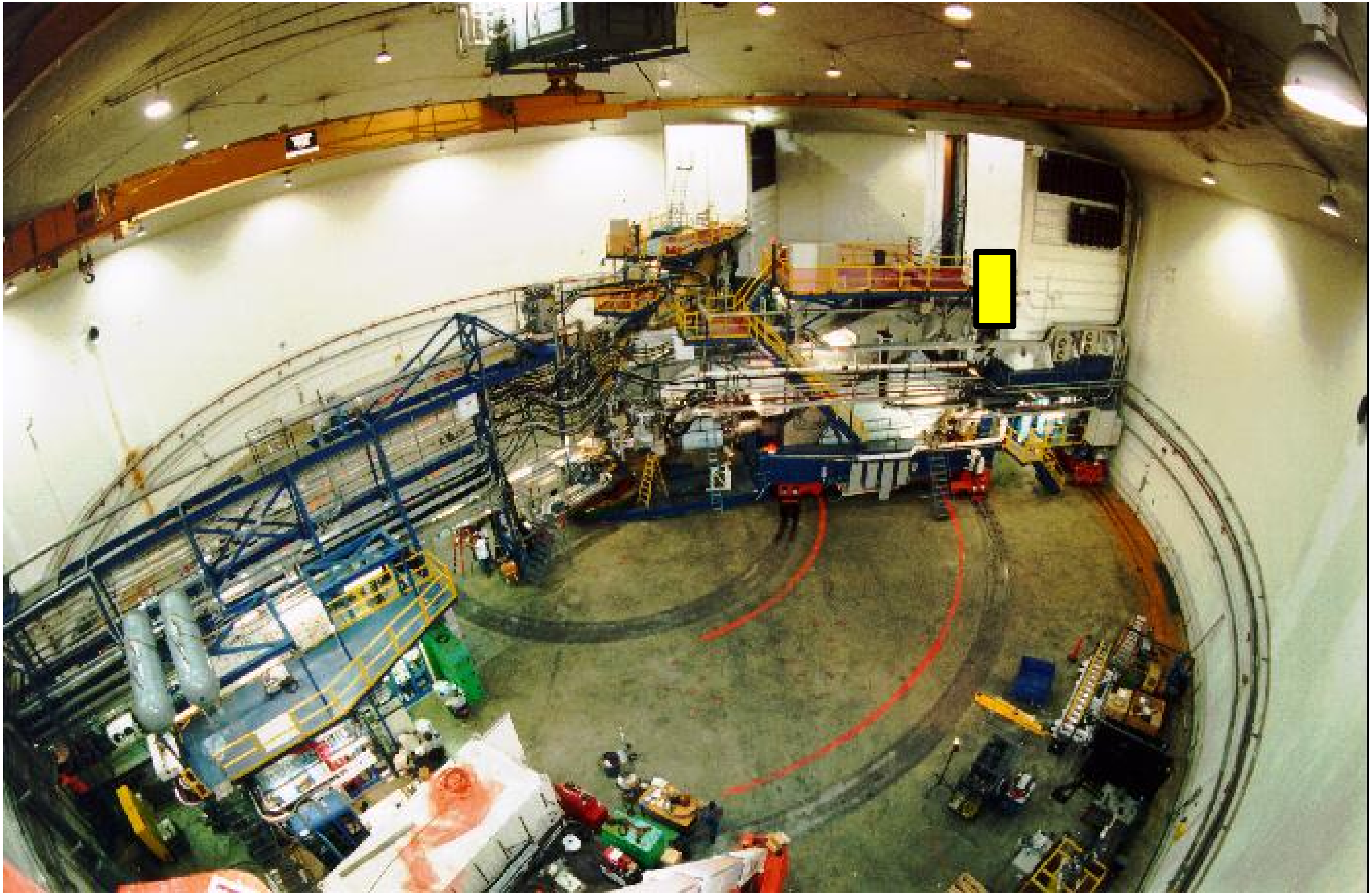
"parity-quality" beam since 1998 K. Paschke (PAVI06&09)

- Helicity-correlated fluctions in beam characteristics:
  - PVDIS asymmetry (100-200ppm) is much larger than other JLab PV experiments: HAPPEX(s), PREX, G0, Qweak;
- Beam polarimetry: at 3 GeV, ~1% from Compton is within reach, should be even easier at 6 GeV;
- Beam transverse asymmetries: will measure for 8-16hrs, orient beam spin in horizontal directions, goal: <0.5%;
- Q^2: same method to determine θ as HAPPEX-III (watercell target) <0.5%;
- DAQ
  - Current Hall A HRS DAQ: Max event rate 4KHz (VDC limited);
  - Previous Hall A PV Experiments (HAPPEX) used Integrating DAQ
  - Will not work for DIS (high rate with large pion background), a new fast counting DAQ is needed

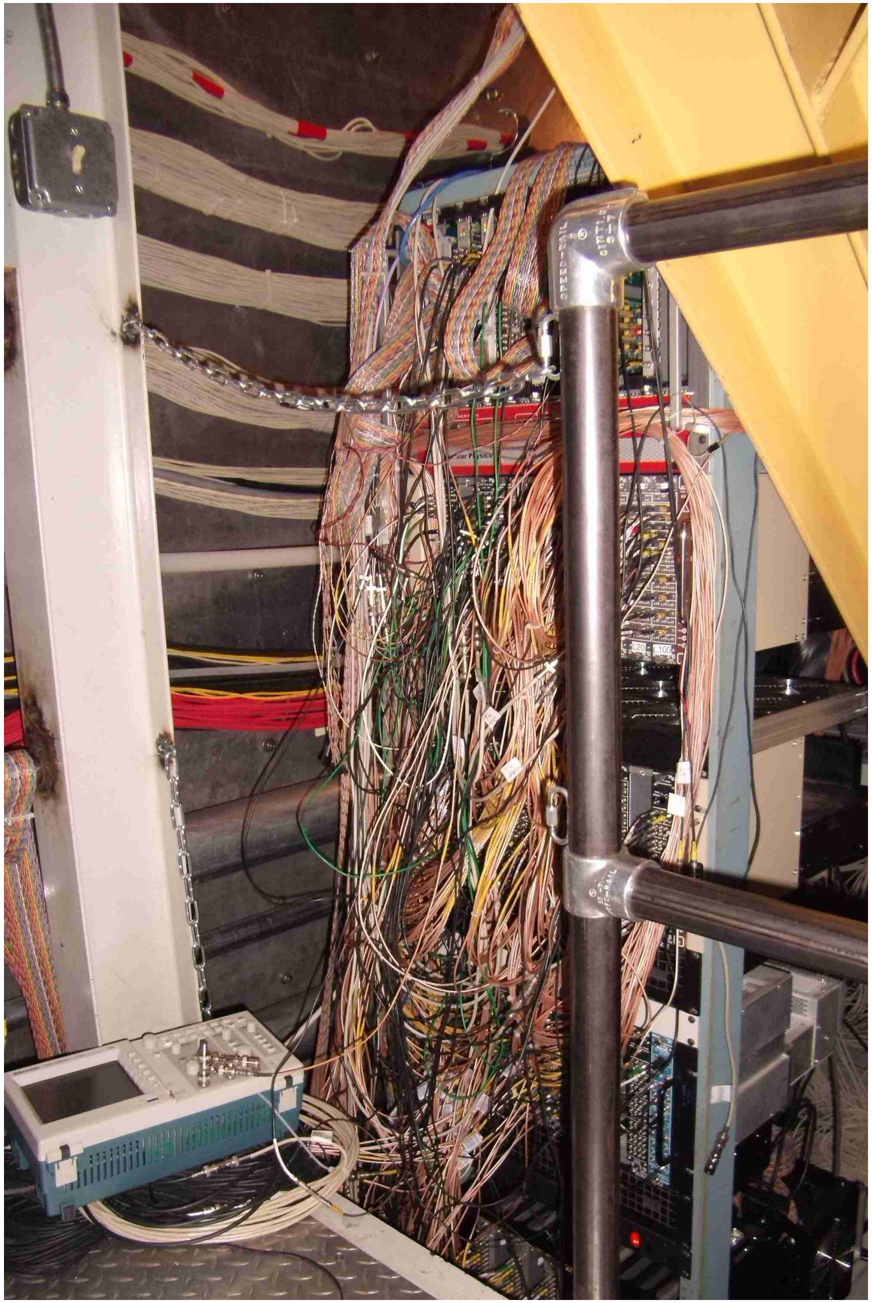
A New Fast-Counting DAQ

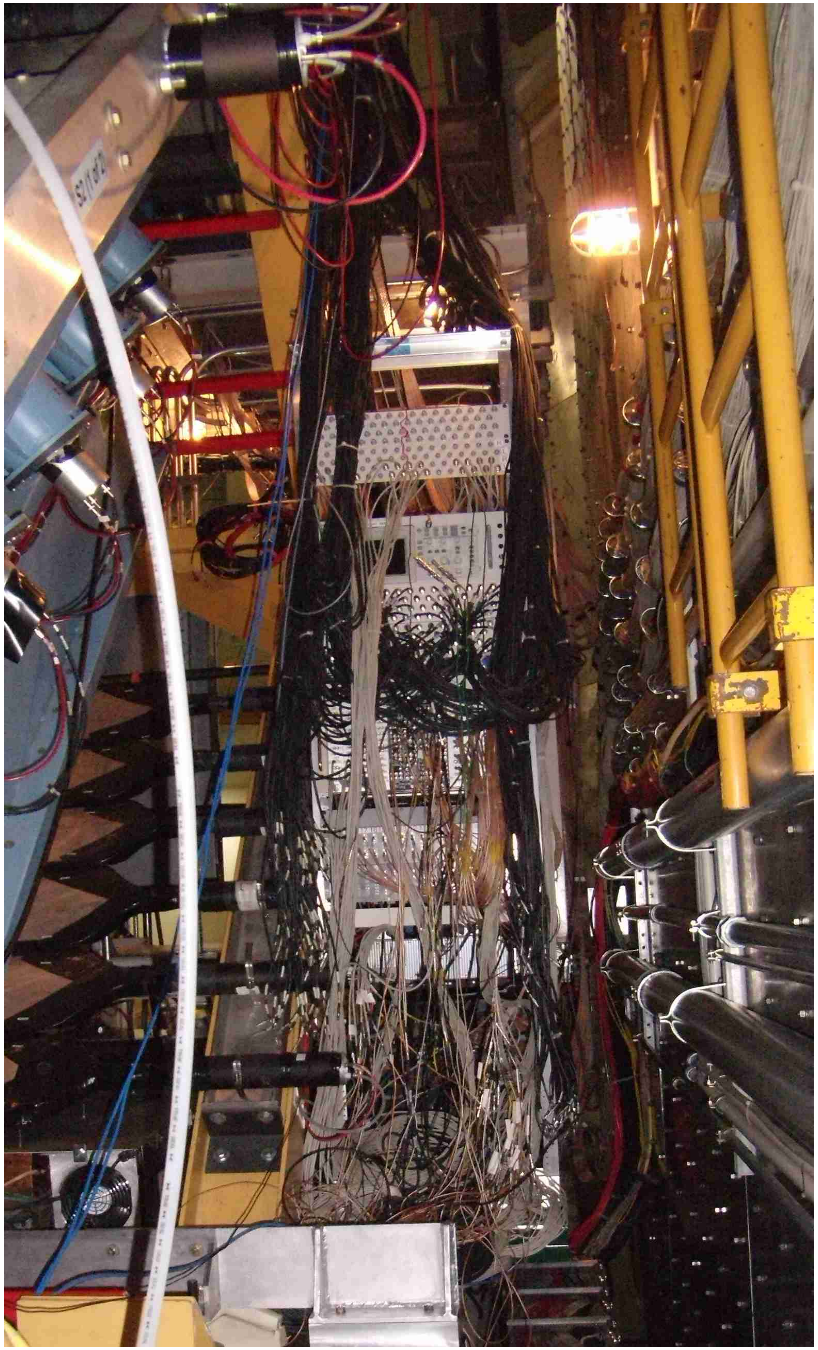
- A new fast-counting DAQ is required:
  - Hardware-based PID, scaler counting up to 1MHz;
  - Full event information sampled at lower rate by HRS DAQ for kinematics, efficiencies and PID analysis;
- *DAQ was tested off-line July-September 2008, including measurement of known asymmetries and 3 independent deadtime measurements.*
- *Installed in the Right HRS and tested parasitically April-June 2009 (polarized target experiments), including 16 hours of 6 GeV beam up to 100uA on a thin carbon target on June 16.*

Experimental Hall A



PVDIS DAQ in Situ

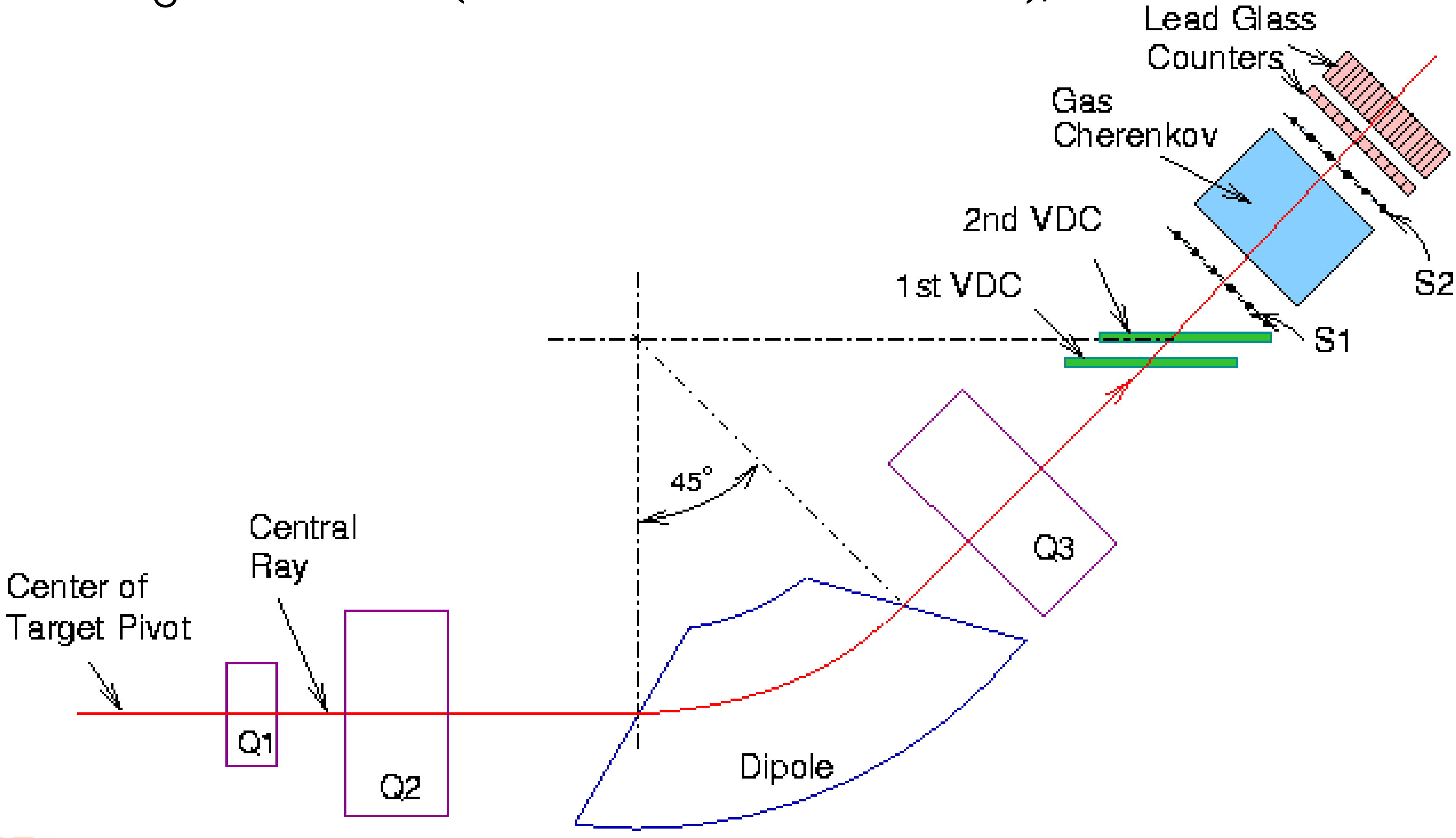




AVU UVA

A new fast-counting DAQ

- Inputs:
  - Scintillators ("T1");
  - Gas cherenkov (GC)
  - Lead glass counters ("Pre-shower" and "Shower");



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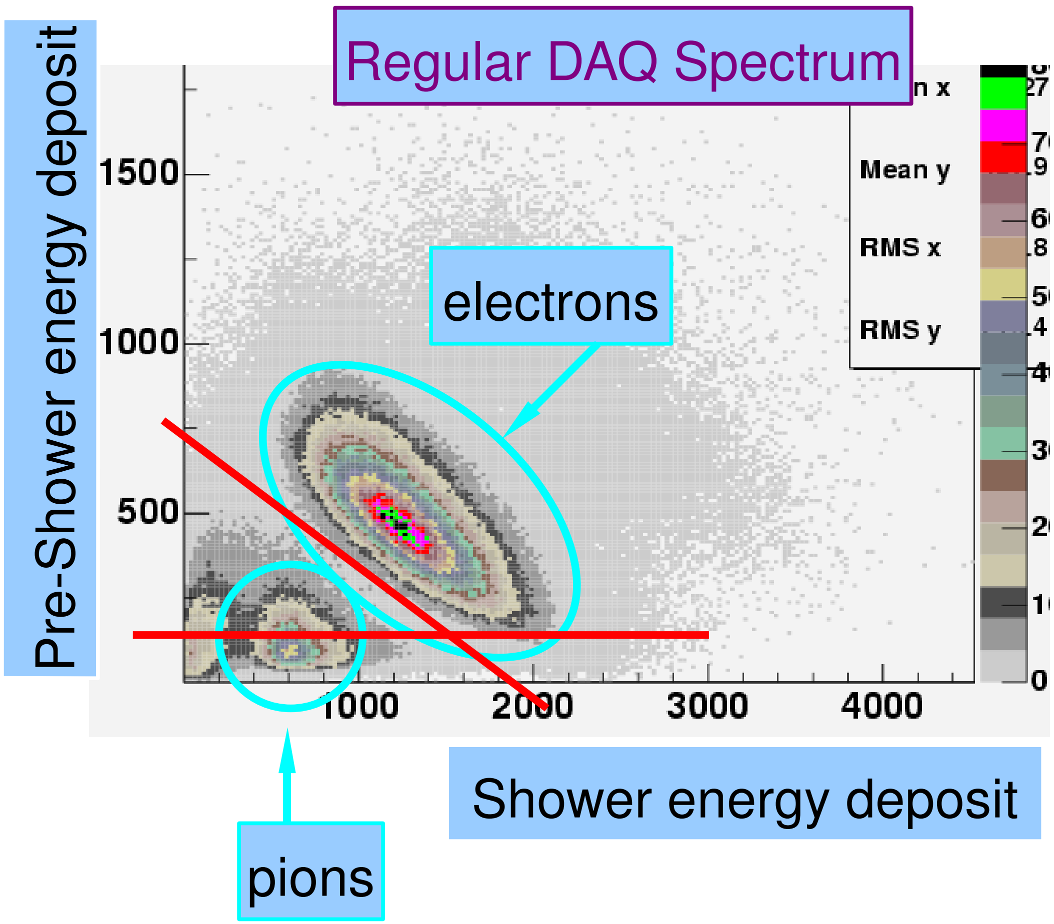
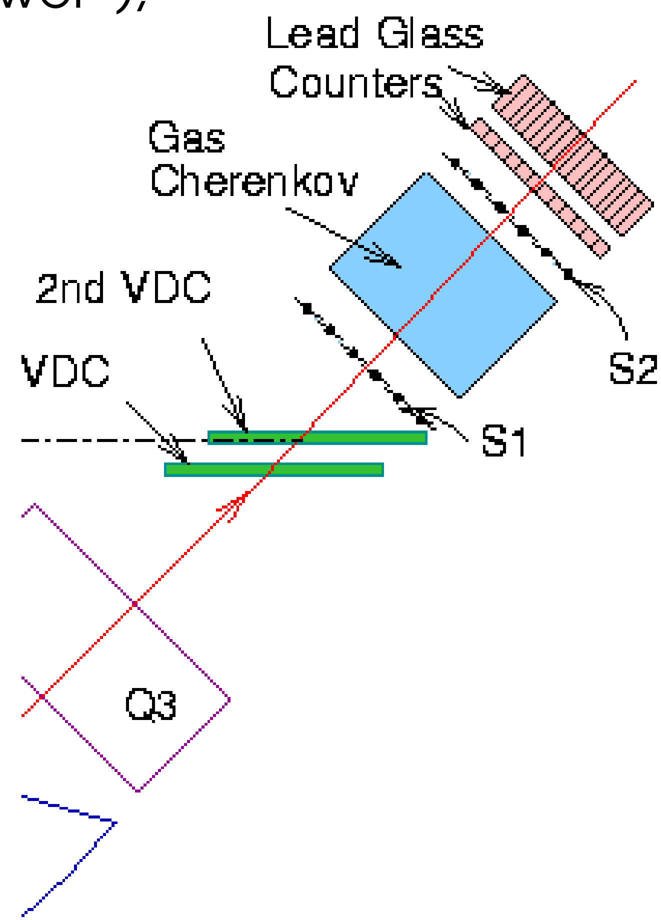
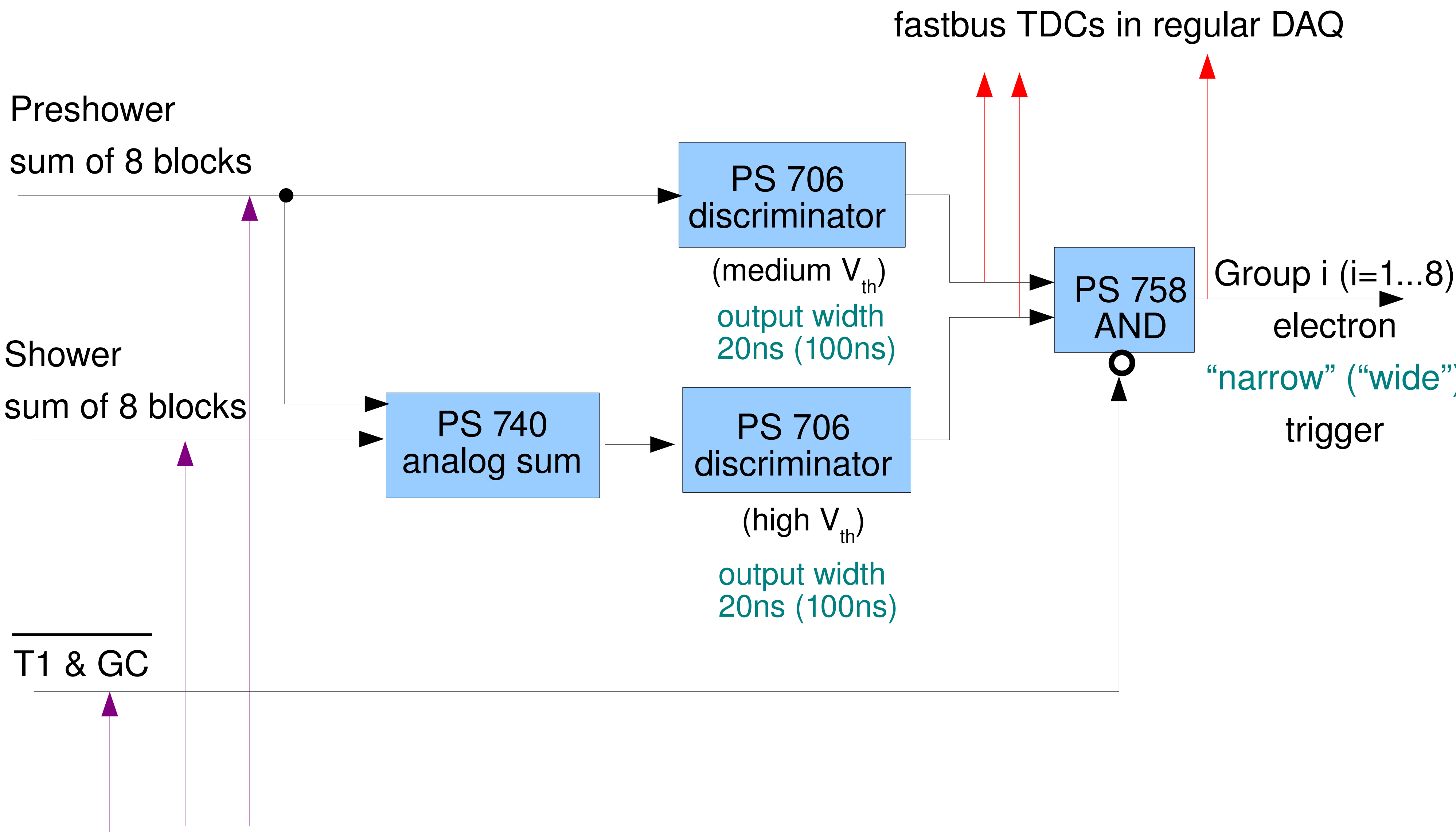




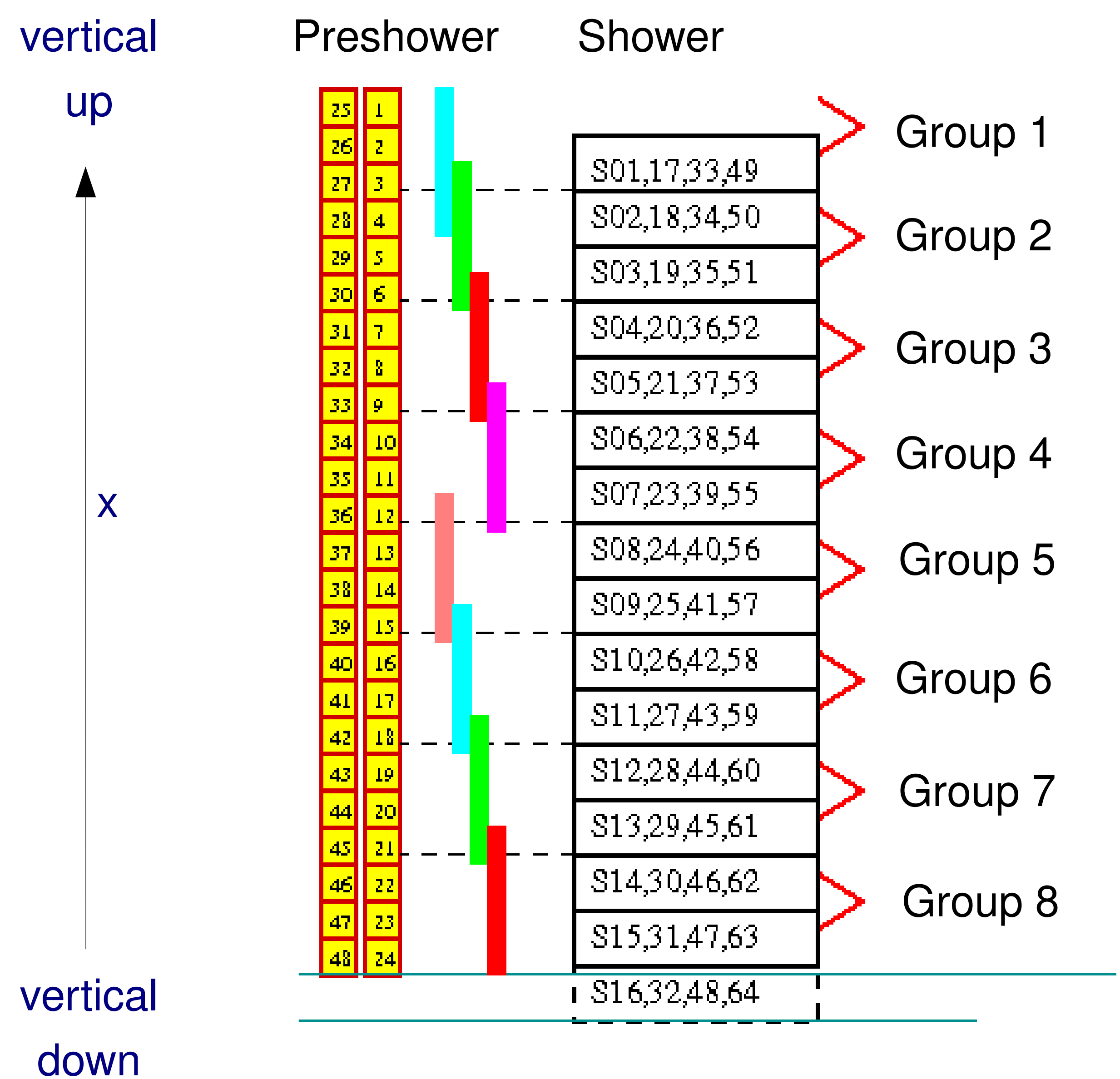
PVDIS DAQ Design



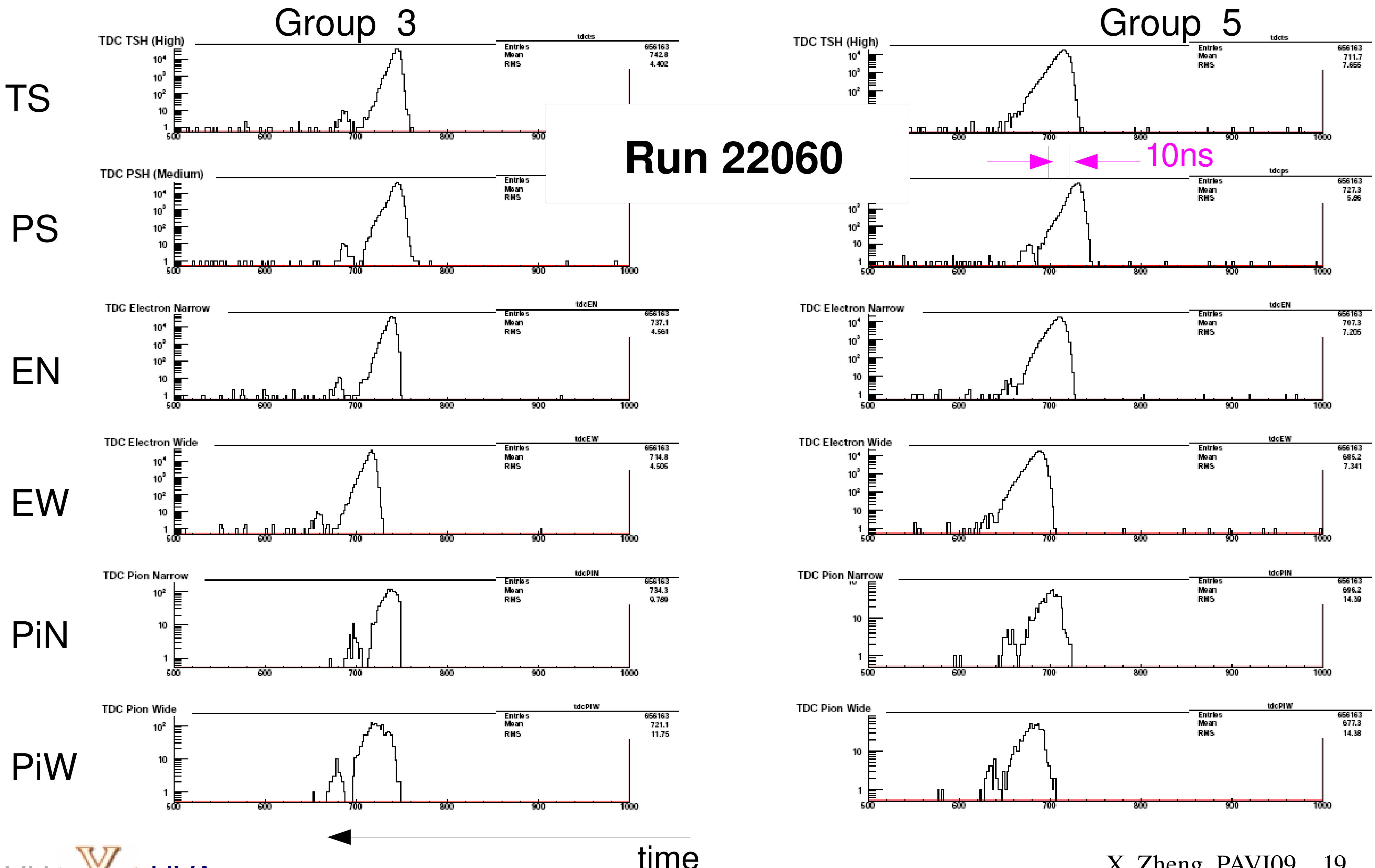
"tagger" (100Hz pulser) added for deadtime measurement (currently for group 5-8 only)

- Goal: $>10^3$ pion rejection

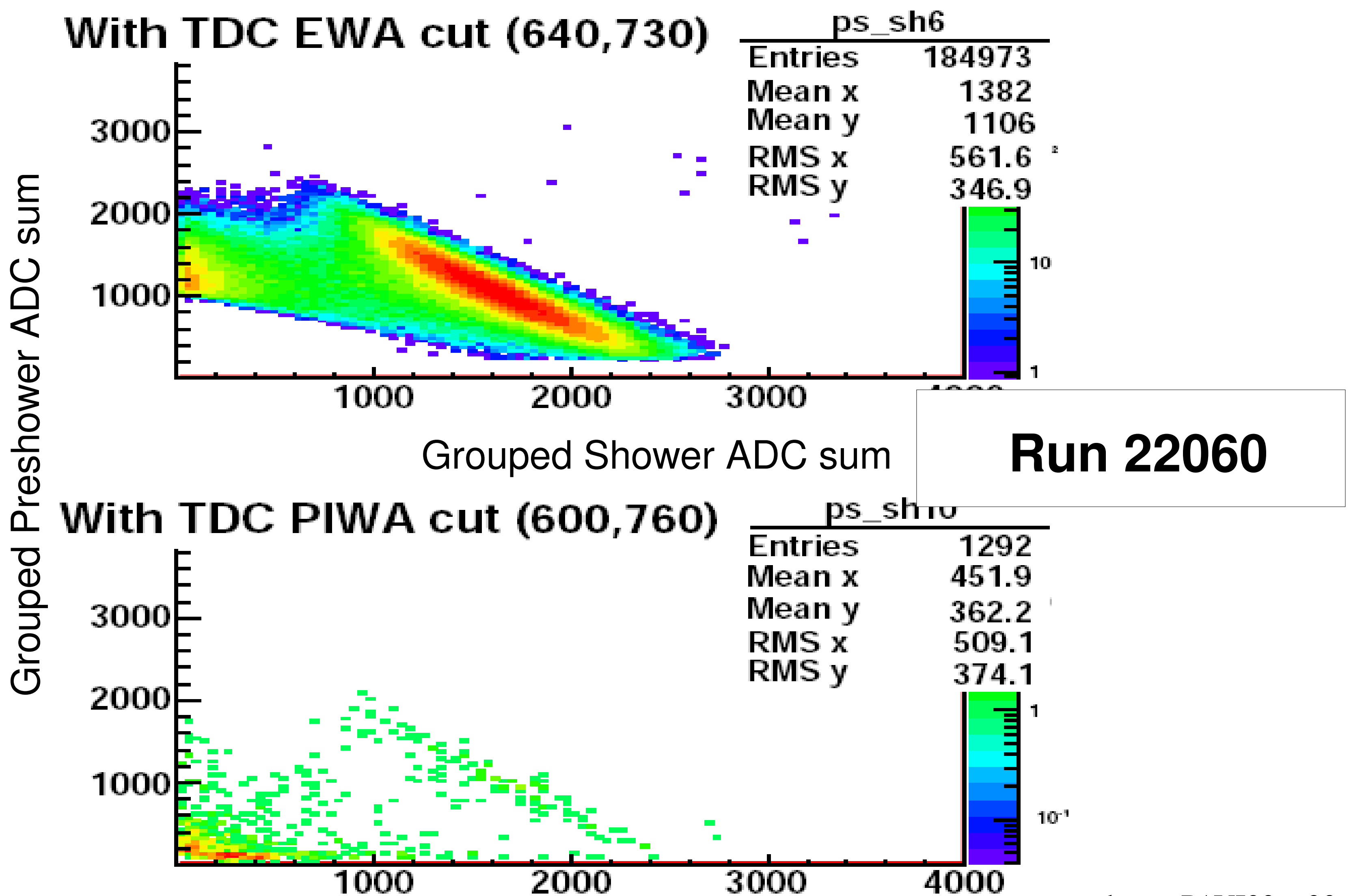
Lead-Glass Grouping Scheme



Parasitic Test Runs — Timing Check using fbTDC info in RHRS DAQ



Parasitic Test Runs — Performance Check using fbTDC info in RHRS DAQ



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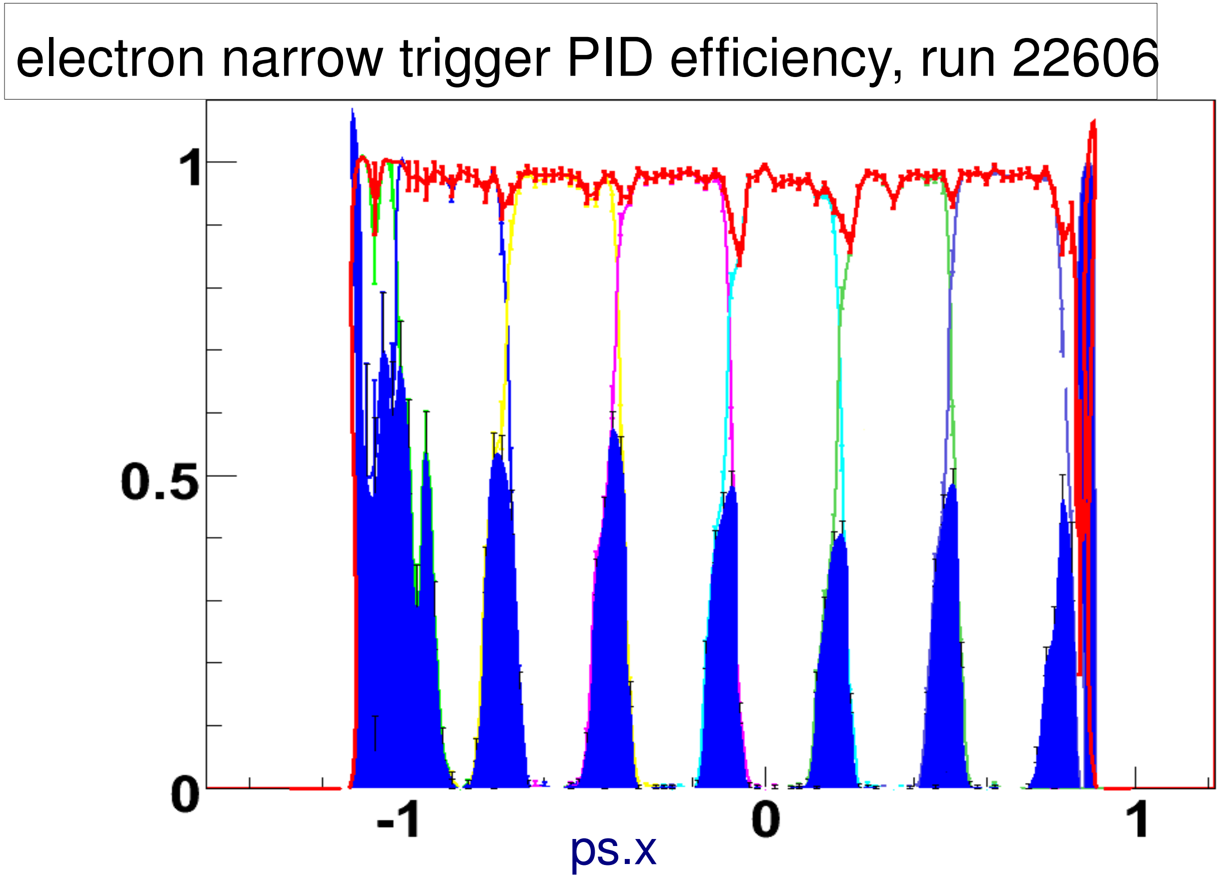
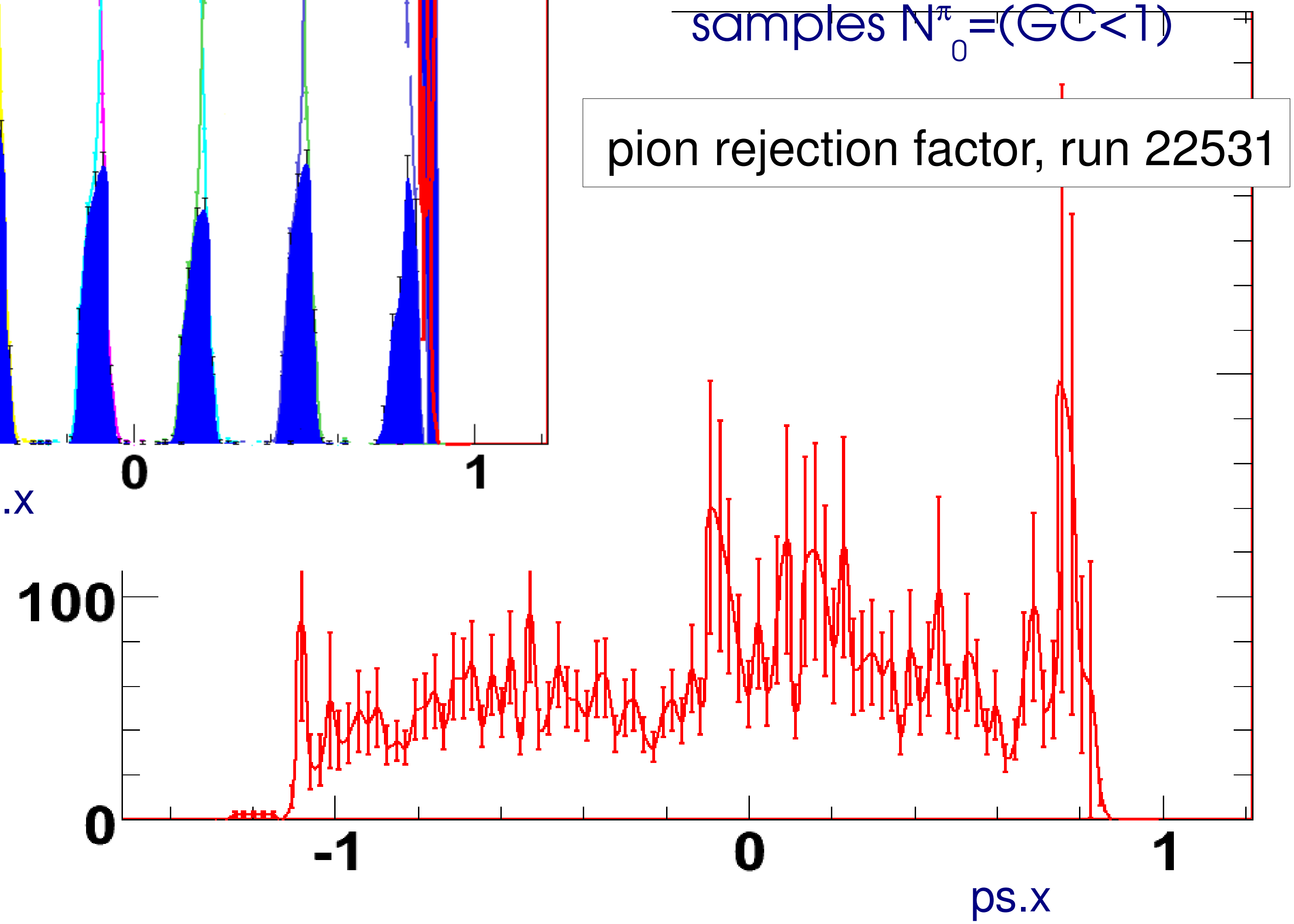
Parasitic Test Runs — Lead Glass PID Check using fbTDC info in RHRS DAQ

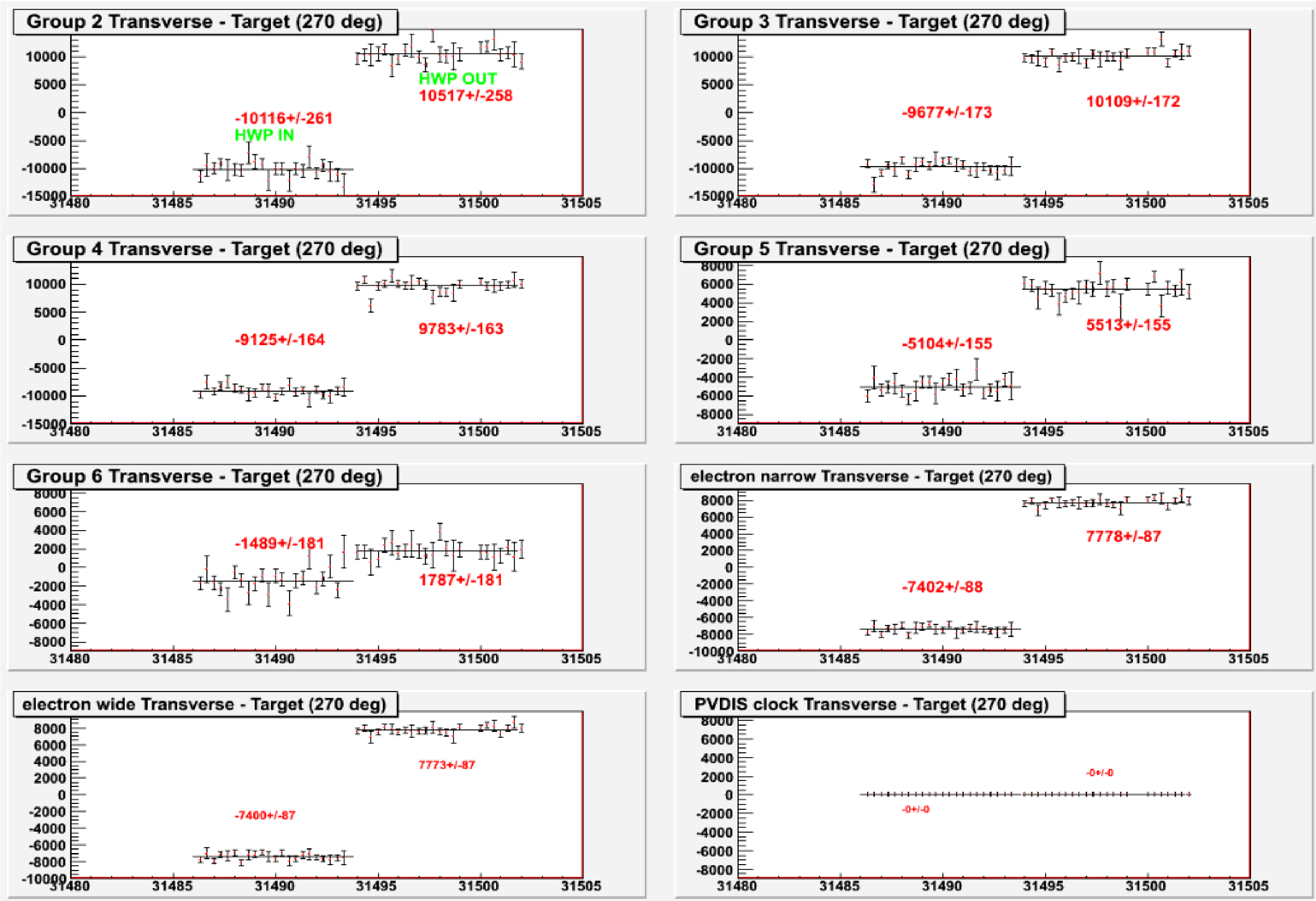


- eff=N^e_1/N^e_0, electron samples N^e_0=(GC>800)
- rej=N^π_0/N^π_1, pion samples N^π_0=(GC<1)



- Both agree with expections
- Can be done online and integrated into simulations

Parasitic Test Runs — Asymmetries (polarized 3He target)



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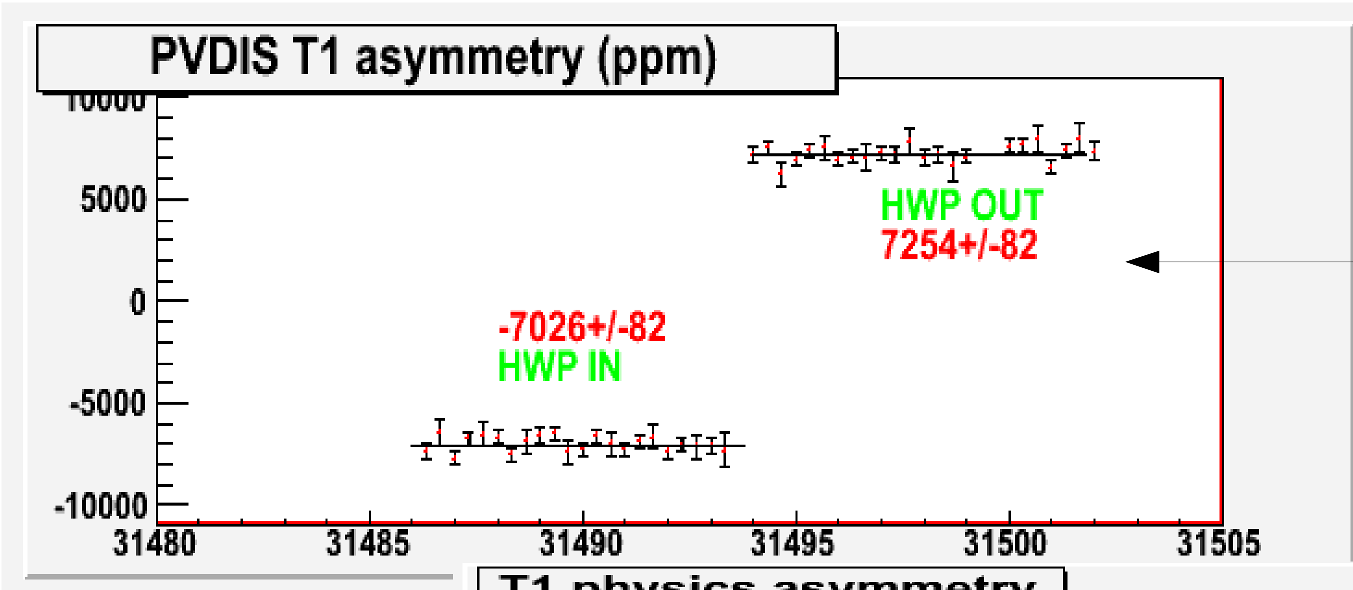
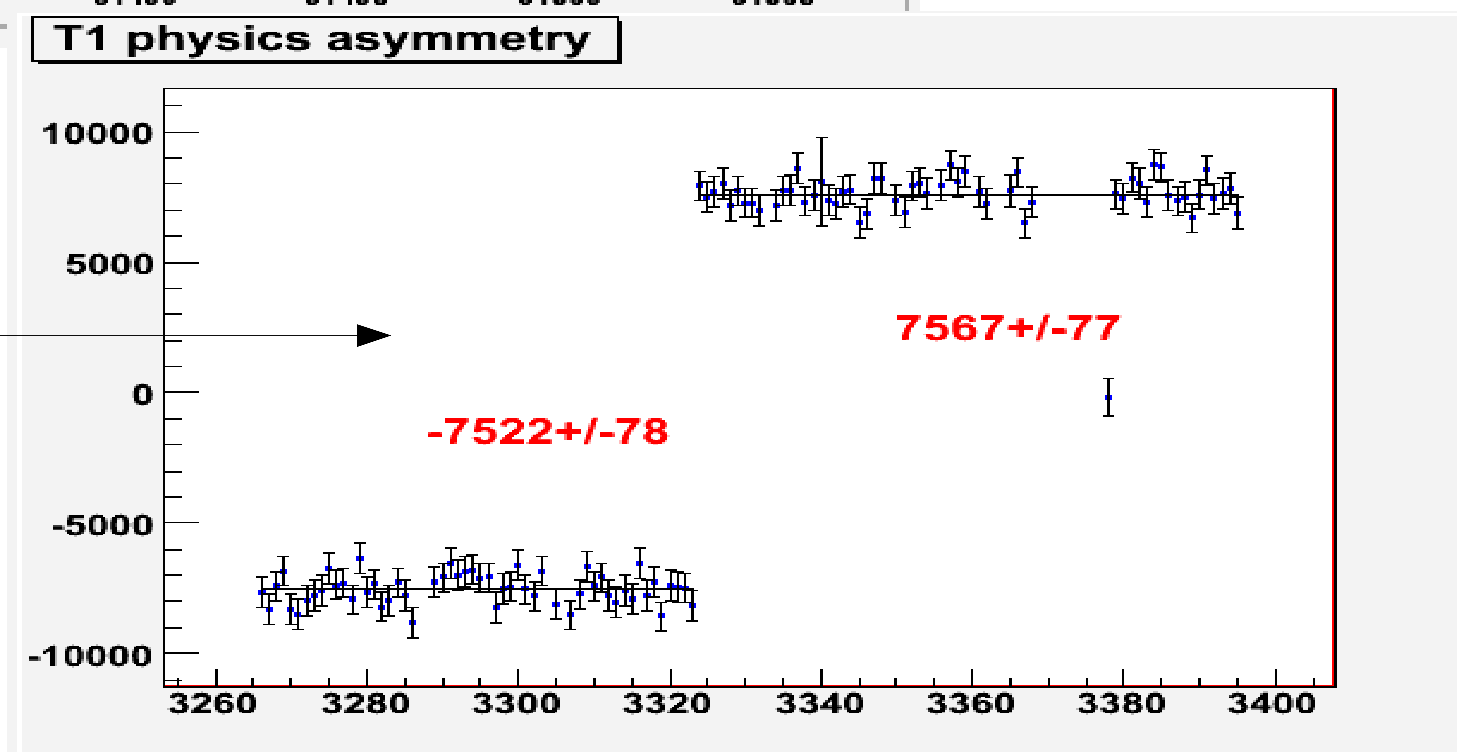
Further Diagnostics needed for Asymmetries



From PVDIS crate, diluted by a 100Hz pulser/1.8kHz, but the shift is not understood



From regular HRS DAQ, before NMR correction (<3%)

- Analysis of 16hrs carbon data underway
- Tests planned July/August

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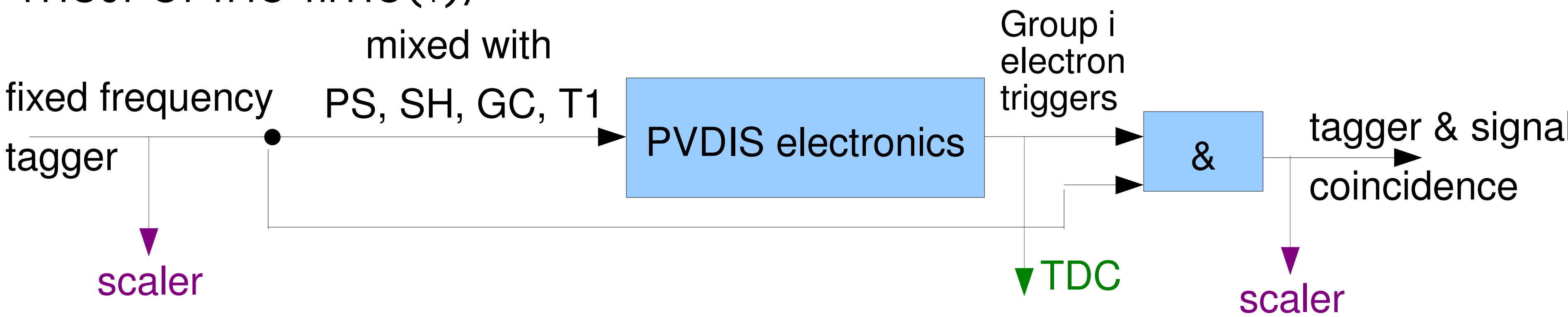
Deadtime Measurement

- Method I: tagger (+TDC) system; cause dilution; can be turned off most of the time(?);

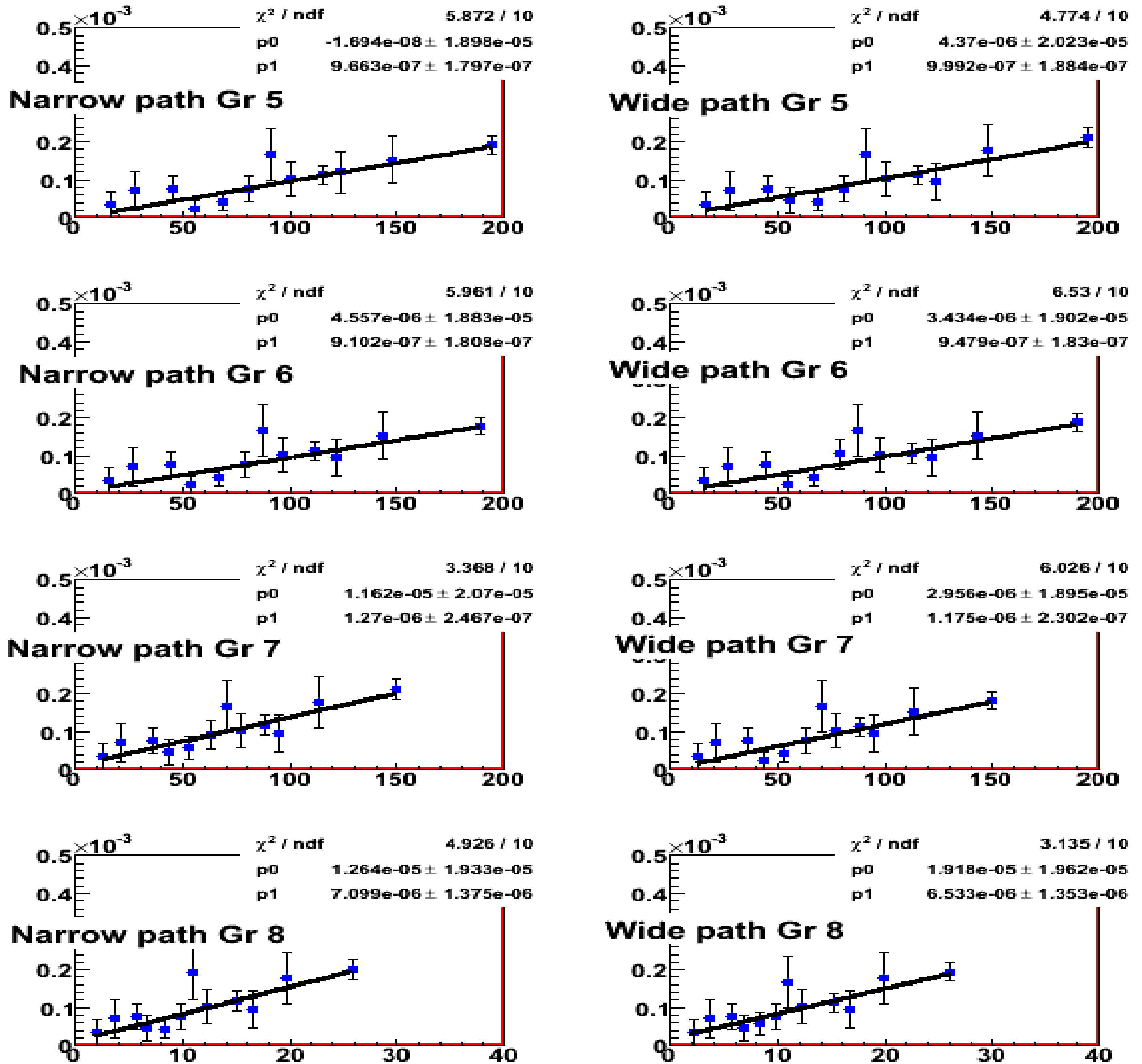


- Method II: TDC "deadzone" (tested off-line, but not observed during parasitic tests because of too low rate);
- Method III: beam current "scan", combined with comparison between the two paths (20, 100ns) — parasitic test data being analyzed;
- Others:
  - trigger simulation (single group already developed);
  - delayed (accidental) coincidence measurement — to be added.

We can learn (have learned) a lot from G0 deadtime measurements.

5-pass Test Runs — Deadtime Study (Method I)

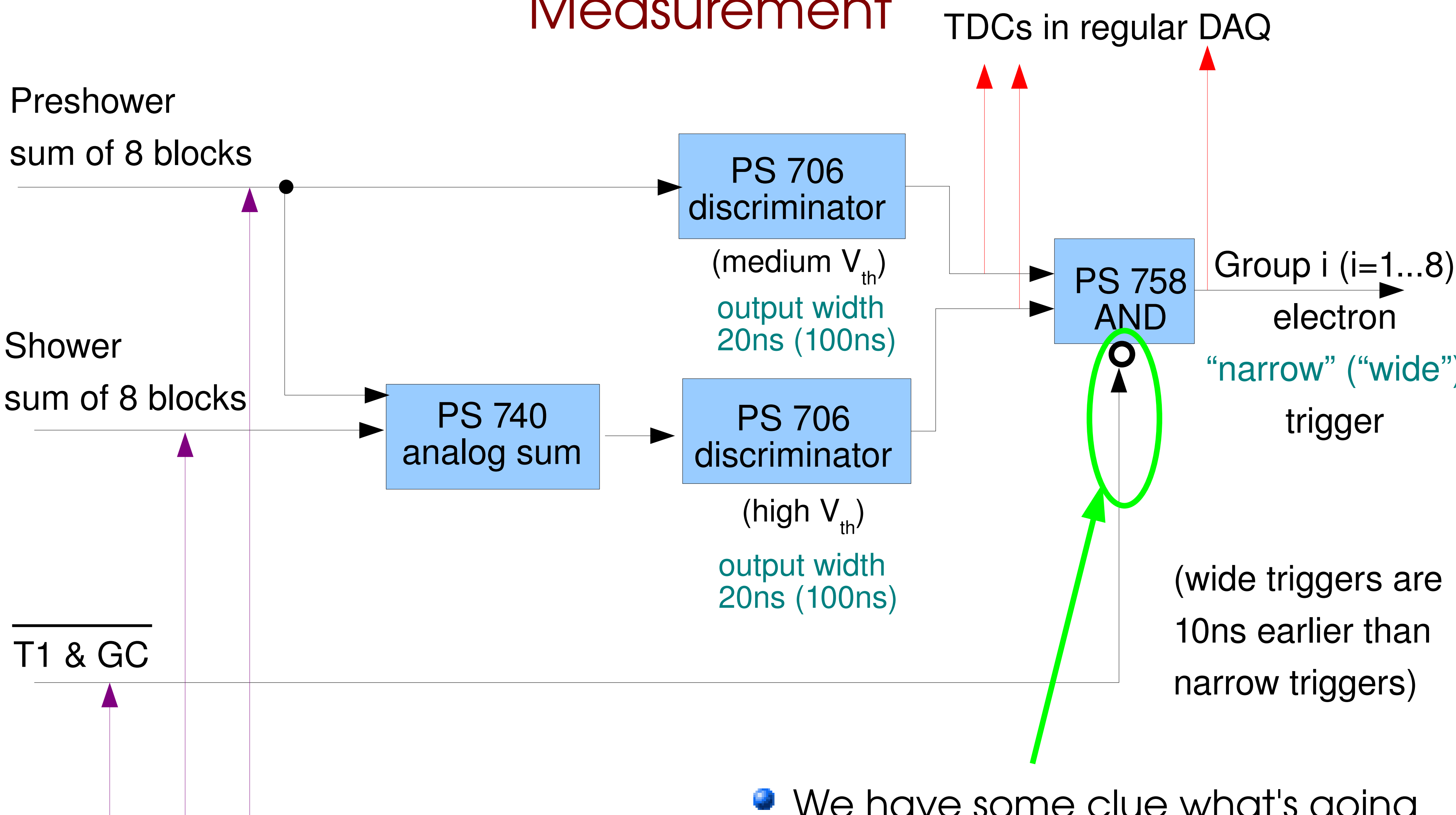
fractional loss in tagger rate



electron trigger rate in each group

- expected rate per group during production: 100kHz
- Goal:measure deadtime to 0.3% (absolute)

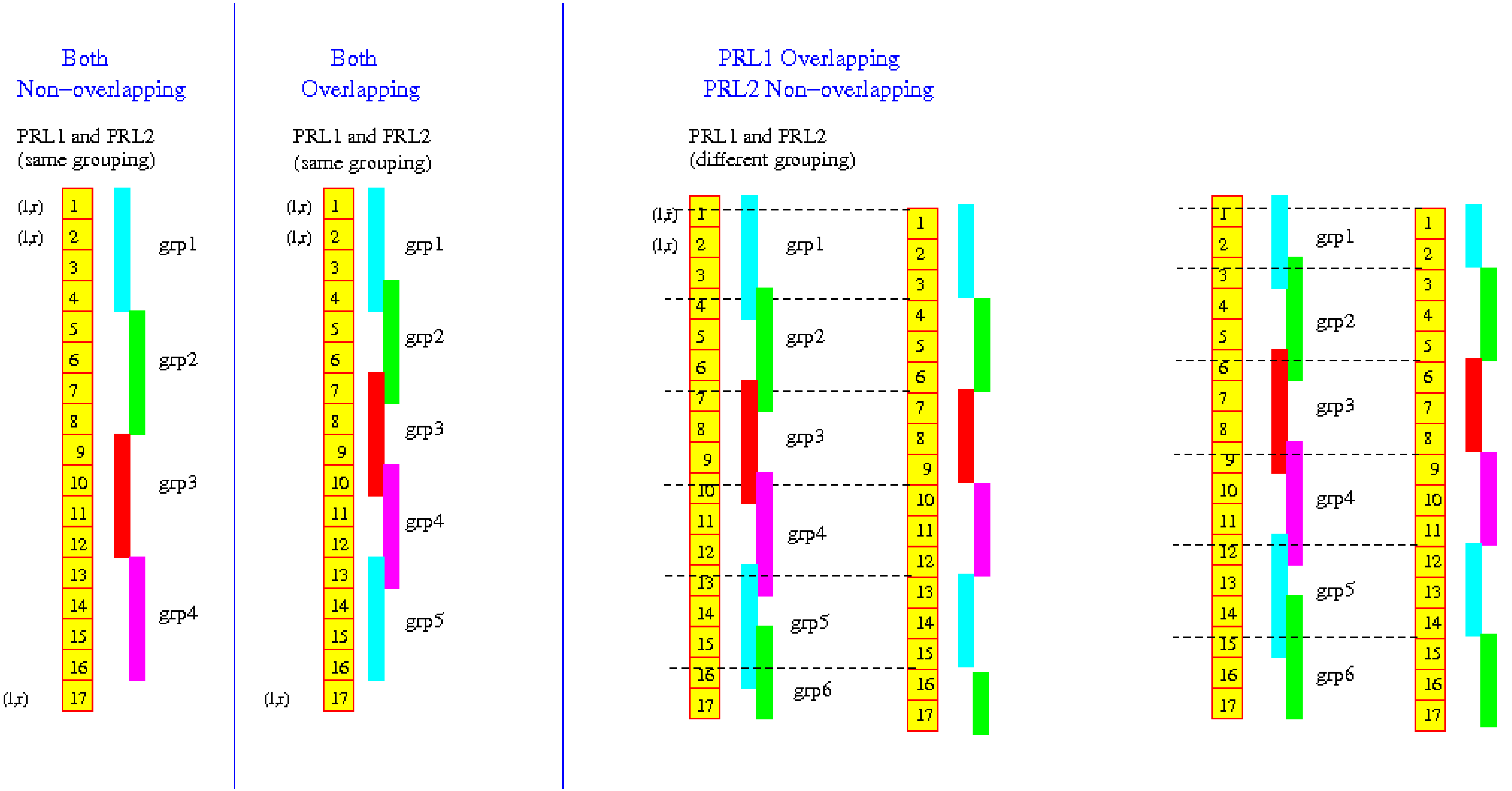
Further Diagnostics Needed for Tagger/Deadtime Measurement



"tagger" (100Hz pulser) added for deadtime measurement (currently for group 5-8 only)

- We have some clue what's going on, and will fix it within the next month.

Check Design for LHRS with “simulation” using ADCs



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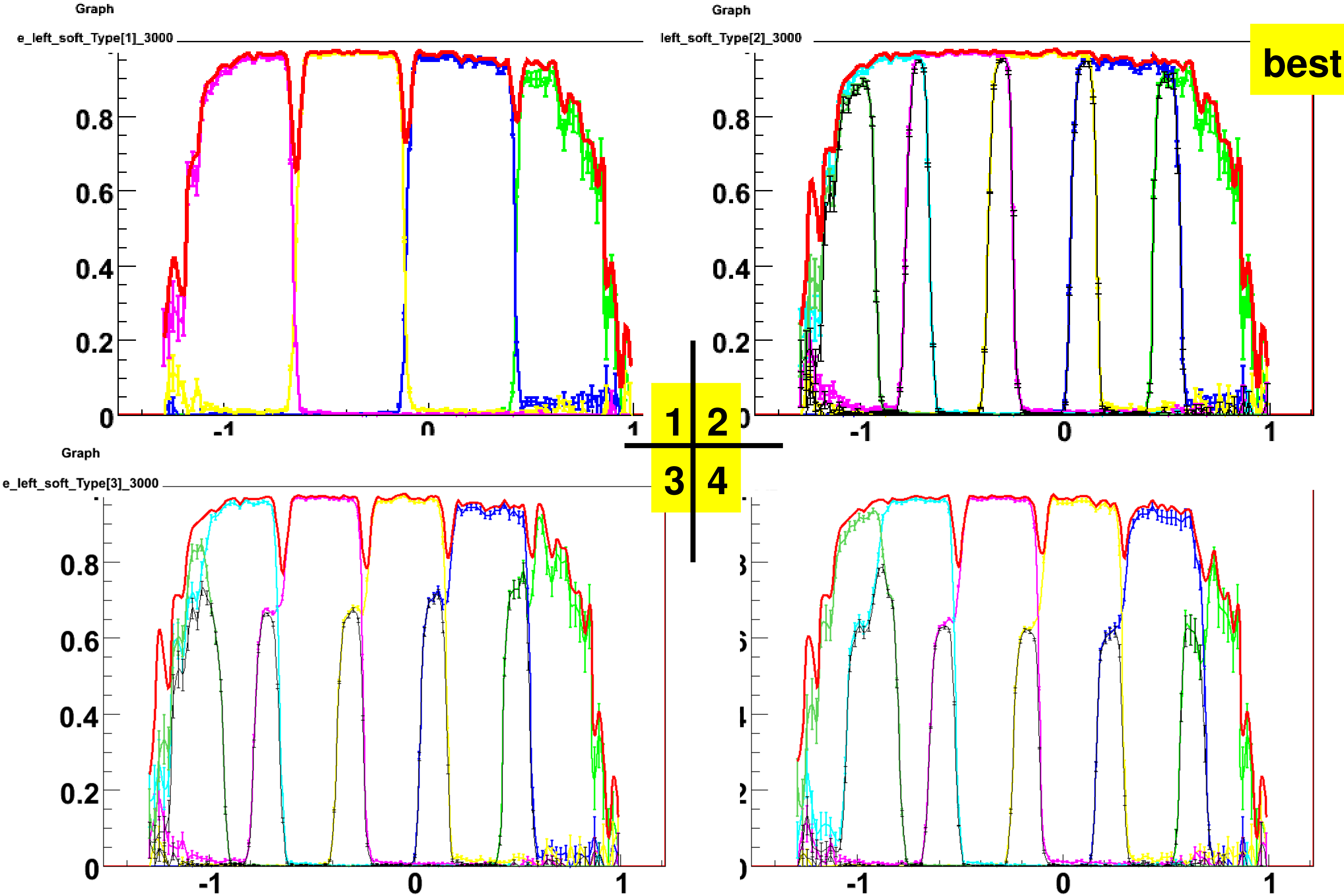


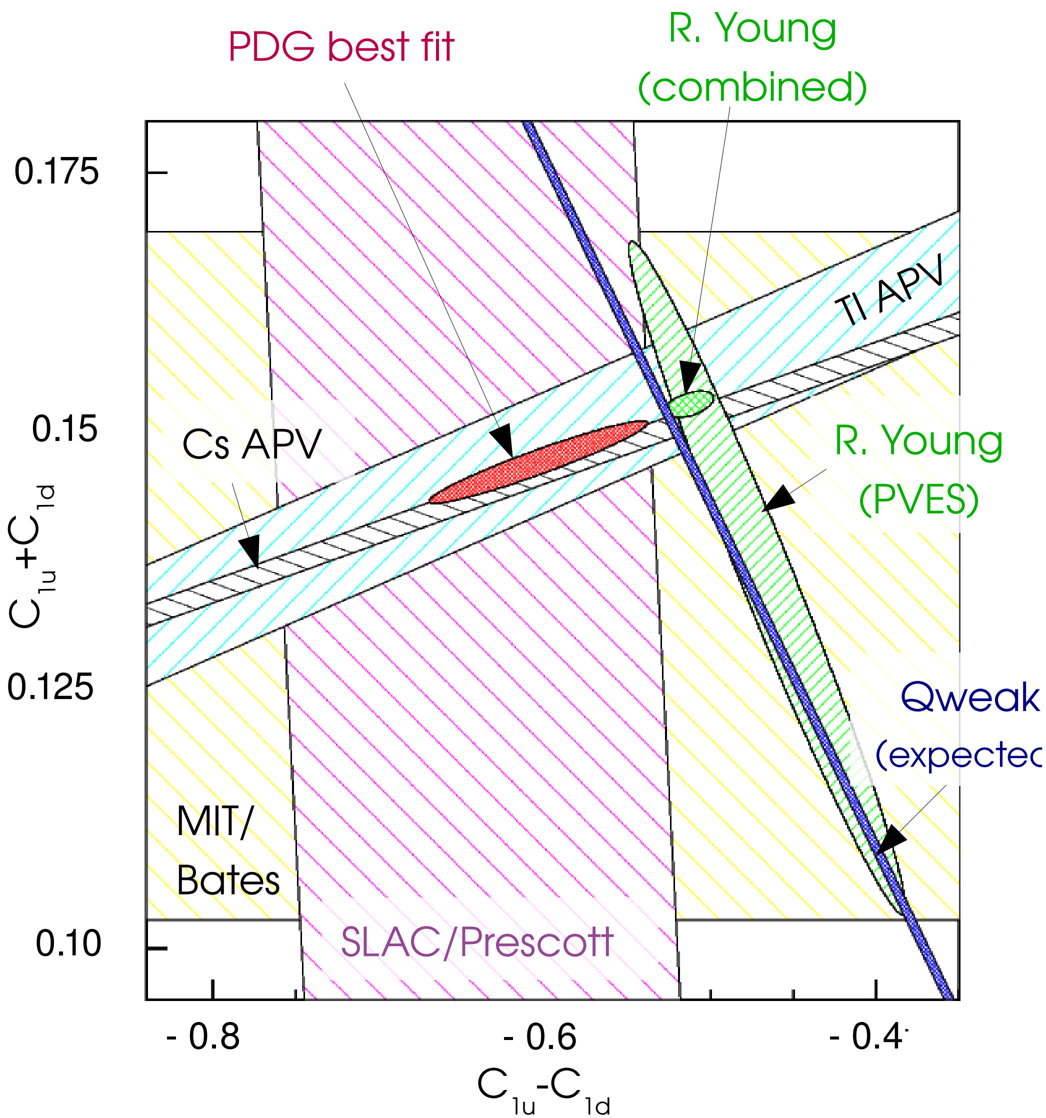
Summary, Plan and Outlook

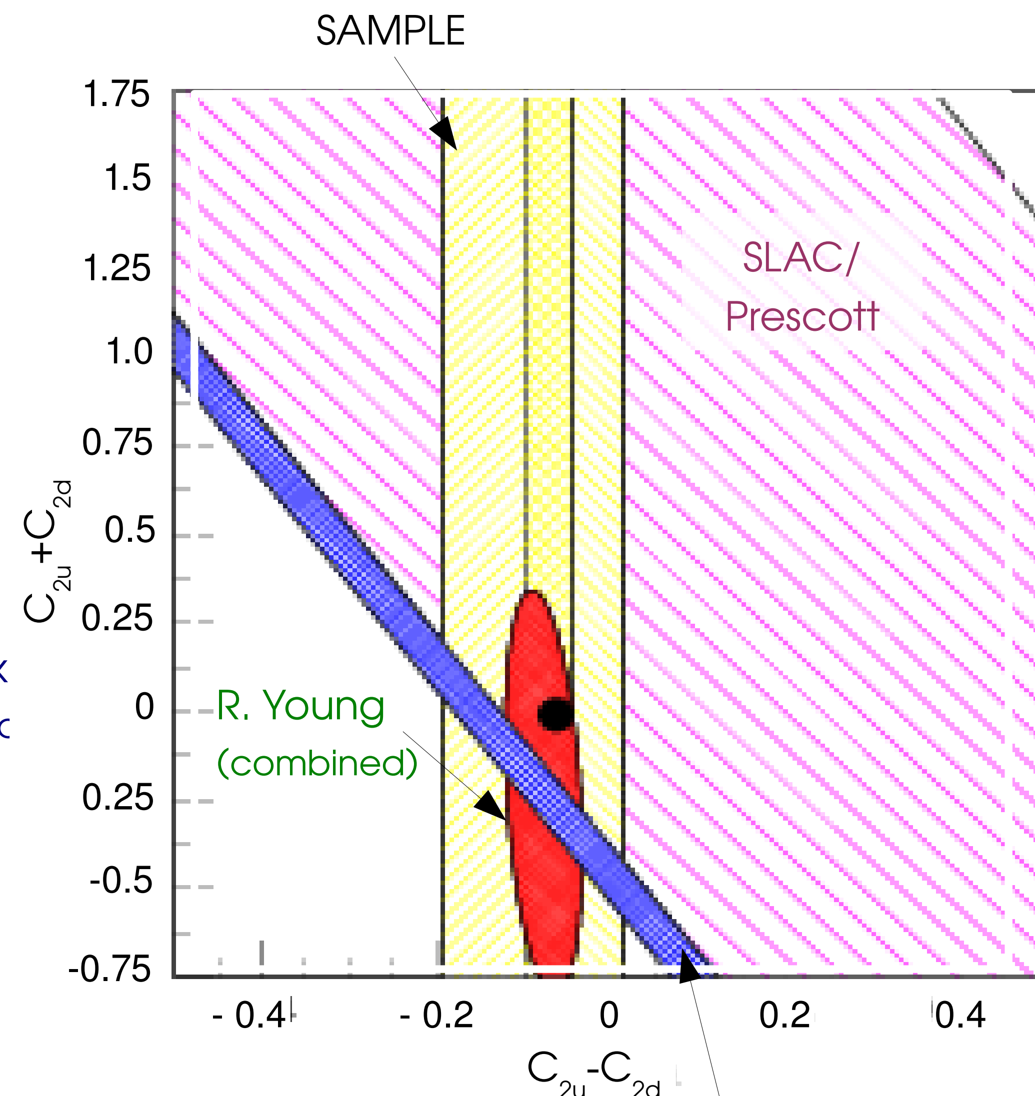
- In the past 6 months, have made great progress in DAQ preparations;
- Now - mid August:
  - further analysis of the parasitic test run data;
  - confirm measurement of null or given asymmetries, investigate possible “shifts”;
  - thorough investigation of the deadtime measurement: tagger (method I) and rate scan (method II);
  - equip some channels with FADCs;
  - assemble and install a (nearly) identical DAQ in the Left HRS;
- November-December: run;

Summary, Plan and Outlook

The 6 GeV E08-011

all are 1 σ limit





Expected: JLab 6 GeV PV-DIS E08-011
(assuming small hadronic effects)

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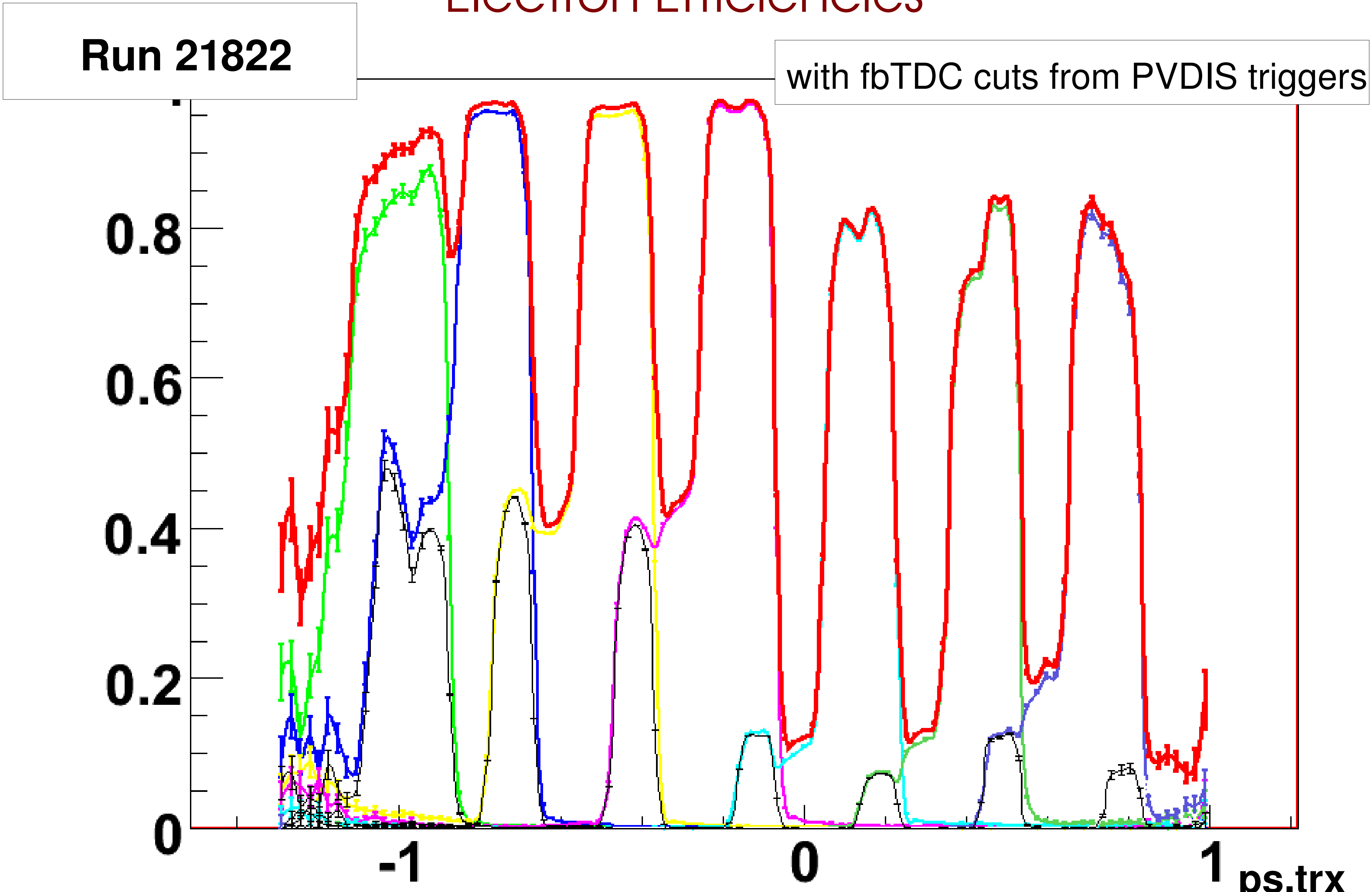
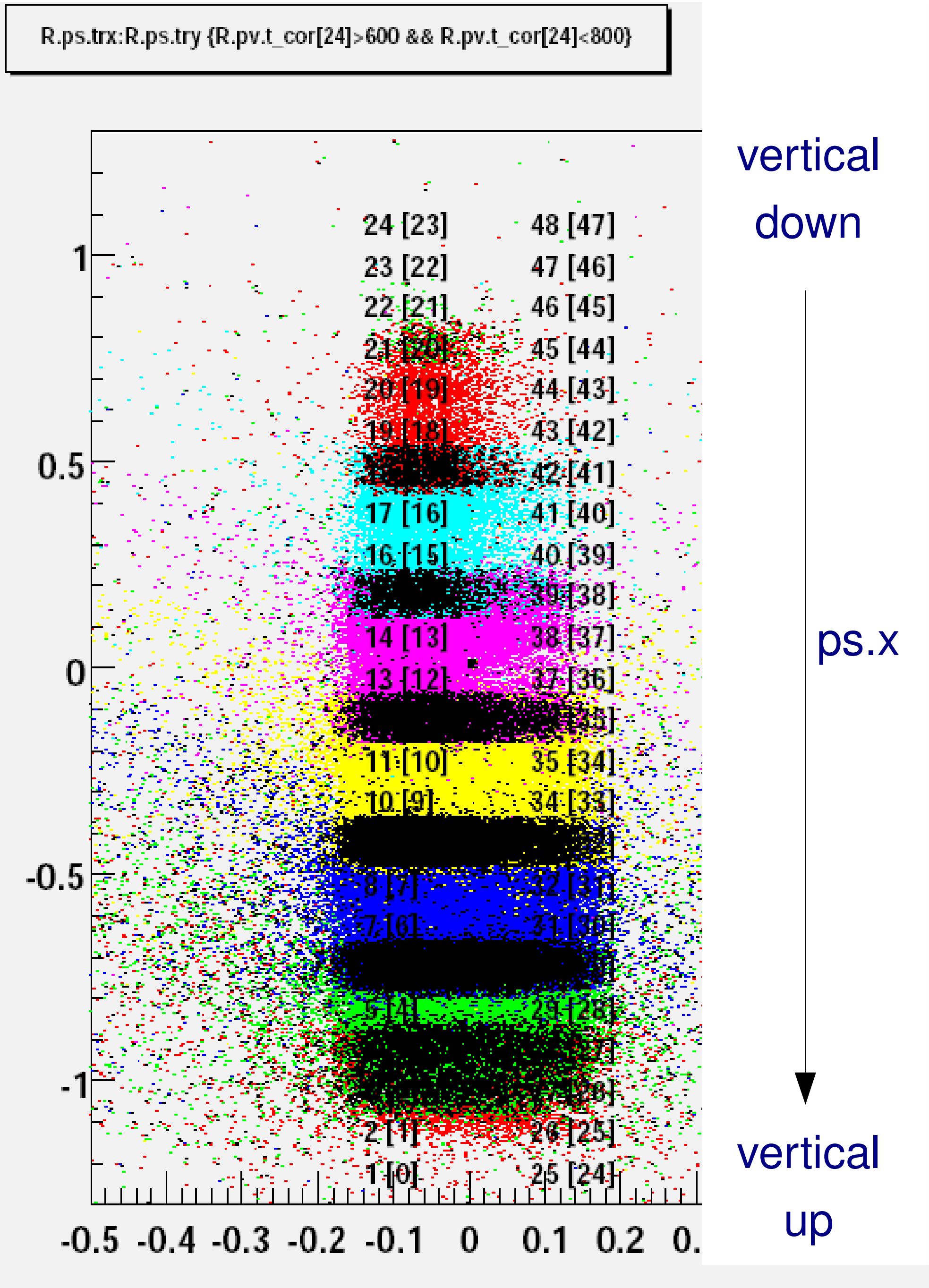
Electron Efficiencies



- *"Holes" not expected!*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UVA