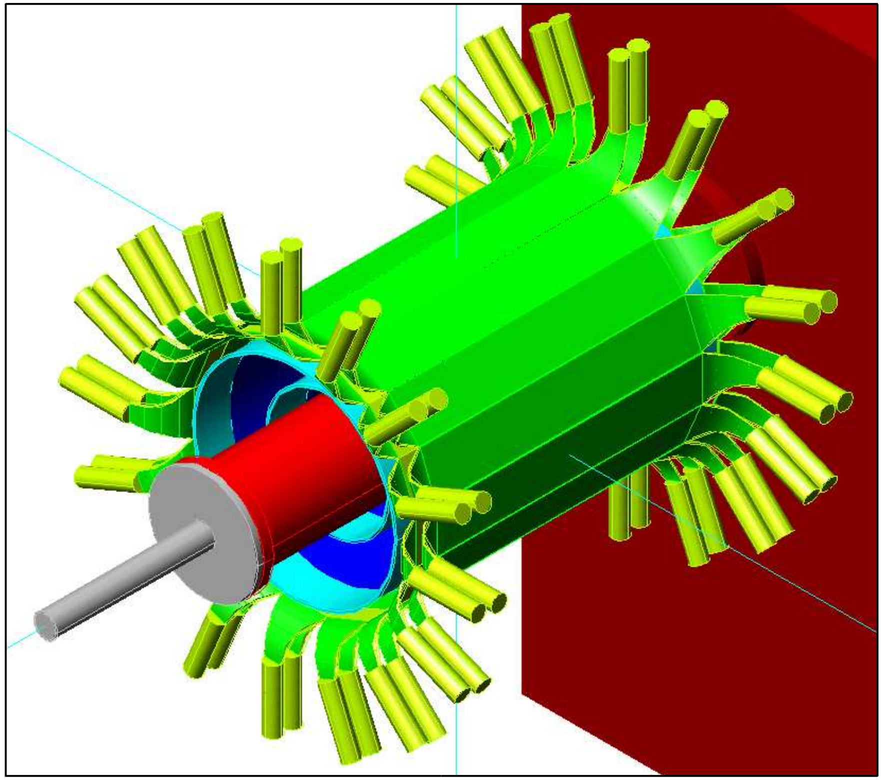
MuCap Run8 Data Analysis: Berkeley Status Report



Tom Banks
UC Berkeley Physics

MuCap Analysis Meeting
UIUC, Illinois
May 2-3, 2005

Presentation Outline

- Overview of the MuCap Berkeley Analysis Software (MBAS) structure and operation
- Results to date
- Remaining (analysis) issues and problems
- Future improvements

MBAS Structure

The MBAS uses the MIDAS Analyzer framework to process the data in successive stages ("multi-stage processing").

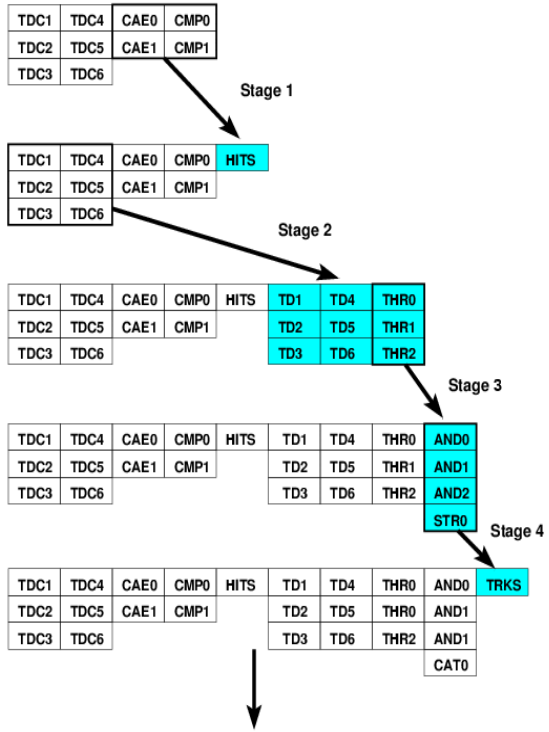
Each module performs a specific task, and the results are passed downstream.

This architecture is powerful and effective, but it does impose some constraints on the flow of information among modules; namely, the information must be packaged into discrete, well-defined "banks."

Modules

MUnCompressRawData
MUnDuplicator
MCaenCompProcessRaw
MRolloverCheckMQL
MRolloverCheckC
MTDC400ProcessRaw
MCamacAdcProcessRaw
MMuSCAnalysisMQL
MMuSCAnalysisC
MMuPC1AnalysisC
MMuPC1AnalysisMQL
MTPCSegmentSniffer
MTPCTrackAnalysisC
MTPCTrackAnalysisMQL
MePC1AnalysisC
MePC1AnalysisMQL
MePC2AnalysisC
MePC2AnalysisMQL
MeSCAnalysisC
MeSCAnalysisMQL
MBlockCuts
MRates
MCoincidenceCalcs
MTPCImpurityCaptureSearch
MCamacAdcC
MCamacAdcMQL

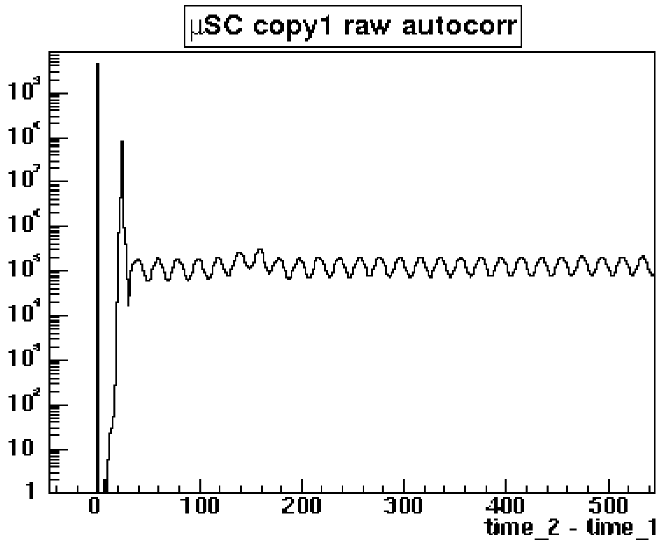
"Multi-stage processing"

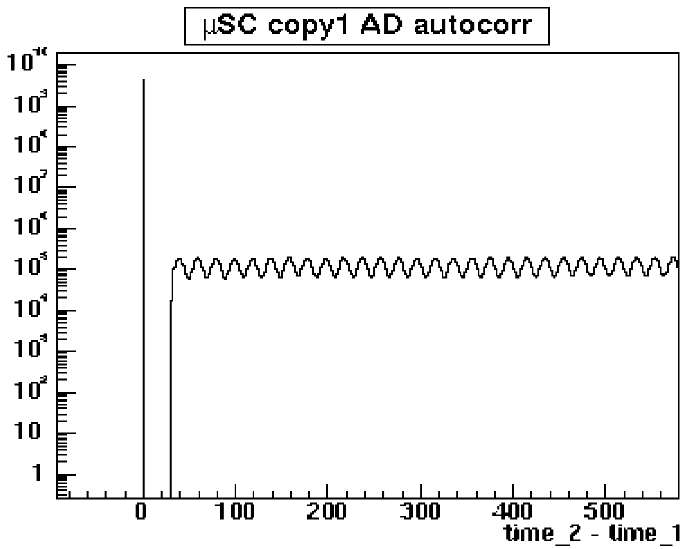


MBAS Muon Identification: muSC

We try to reconcile the different muSC signals (copy1, copy2, routed, etc.), we apply artificial deadtimes to suppress afterpulsing, and we use the muSCA as a veto. Two banks are produced:

- *Good muSC copy1 hits for muon arrival times*
- *Union of all muSC and muSCA hits, for use in pileup protection.*

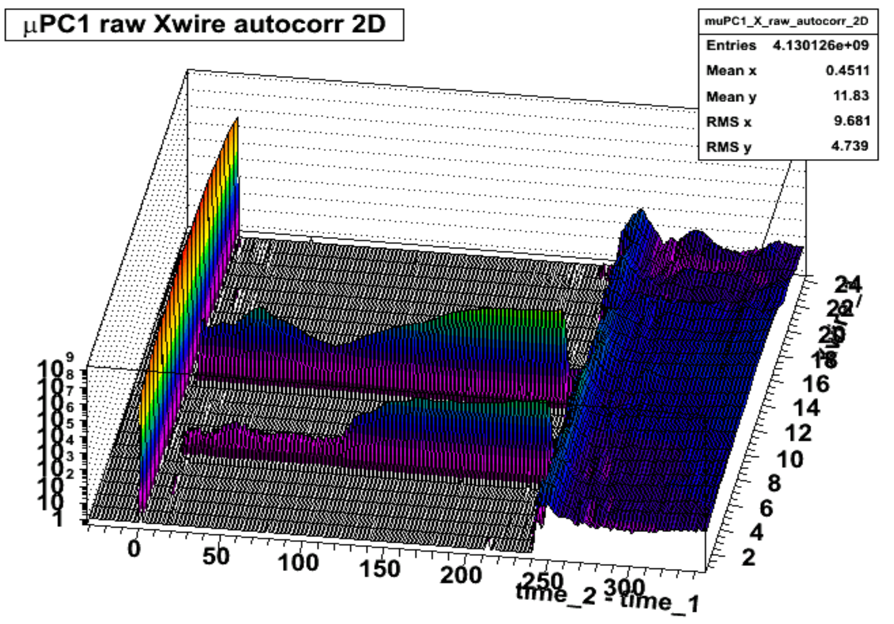


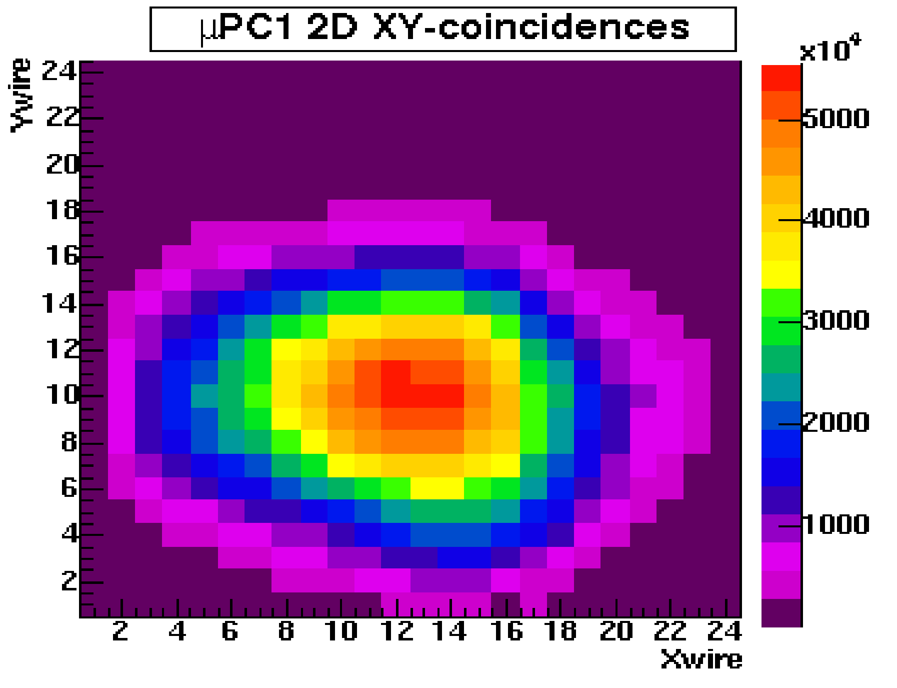


MBAS Muon Identification: muPC1

Each muPC1 plane (X and Y) receives the specific treatment to identify coincidences (more on this later). Two banks are exported downstream:

- *Good 2D muPC1 hits*
- *muPC1 spark times for later spark cuts*

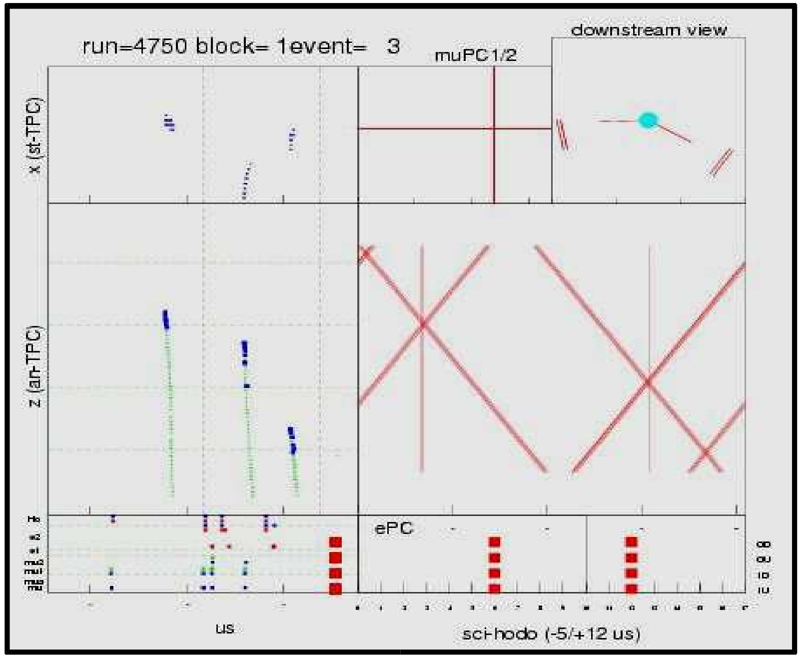




MBAS Muon Identification: TPC

TPC mustop identification sequence:

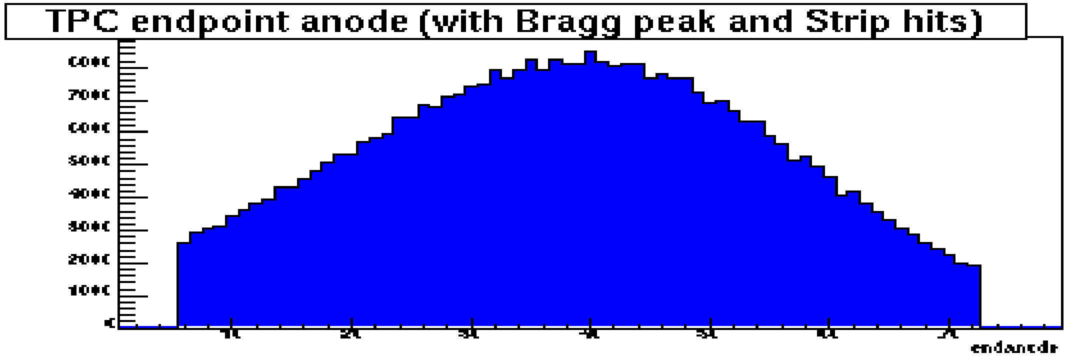
1. *Find anode EH segments in the TDC400 data*
2. *Scrutinize anode EH segments:*
   - I. *must be an "isolated" endpoint (not too much beside or beyond)*
   - II. *must have sufficient lead-up of EL hits (minimum of 5)*
   - III. *cannot be a spark*
   - IV. *must have coincident strip hits (EL or EH)*

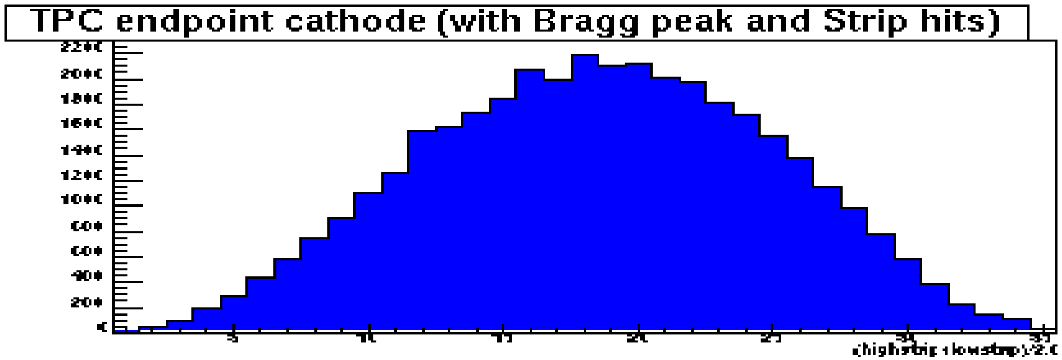


MBAS Muon Identification: TPC

Exported banks:

- *Good stops with strip hits*
- *TPC spark times for later spark cuts*

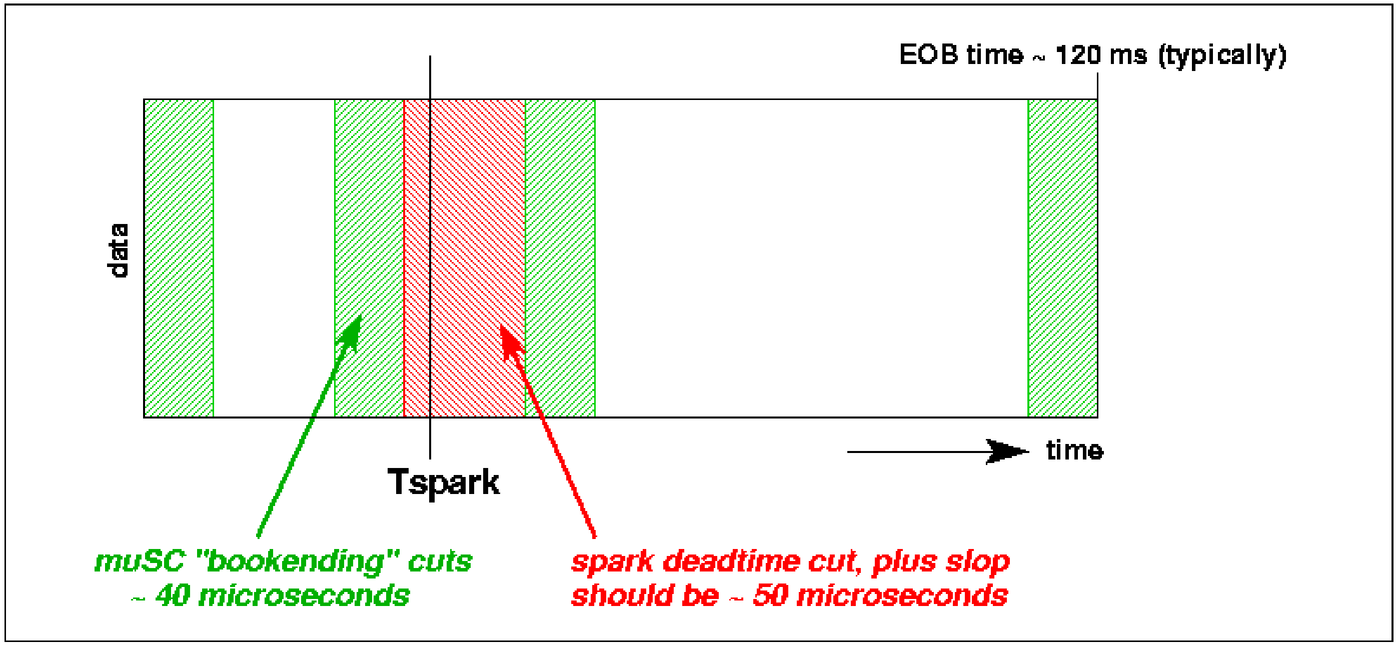




MBAS Muon Identification: Combined Detectors

Combining the muSC, muPC1, and TPC data is relatively straightforward, since we're not worrying about tracking at this point and just forming temporal coincidences. But here are some non-obvious considerations:

- *Bookending (BE)*
- *Spark Cuts (SC)*
- *Pileup protection (using both muSC and muPC1)*



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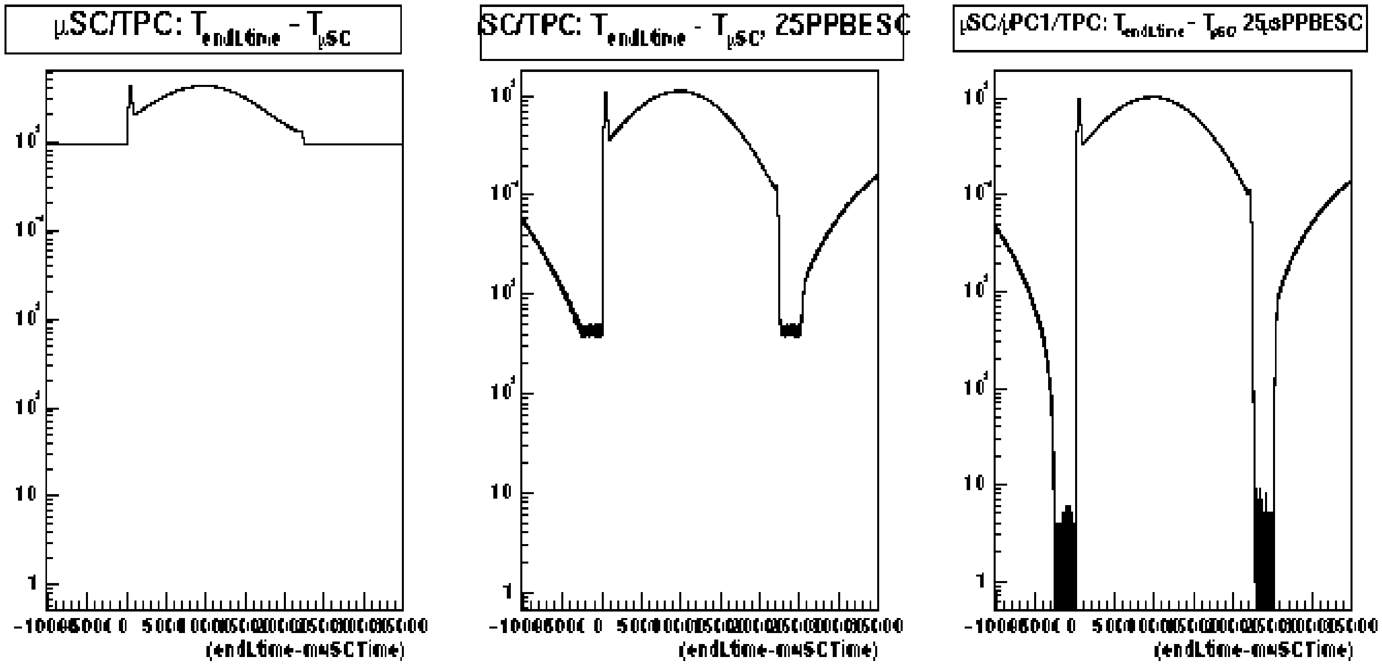
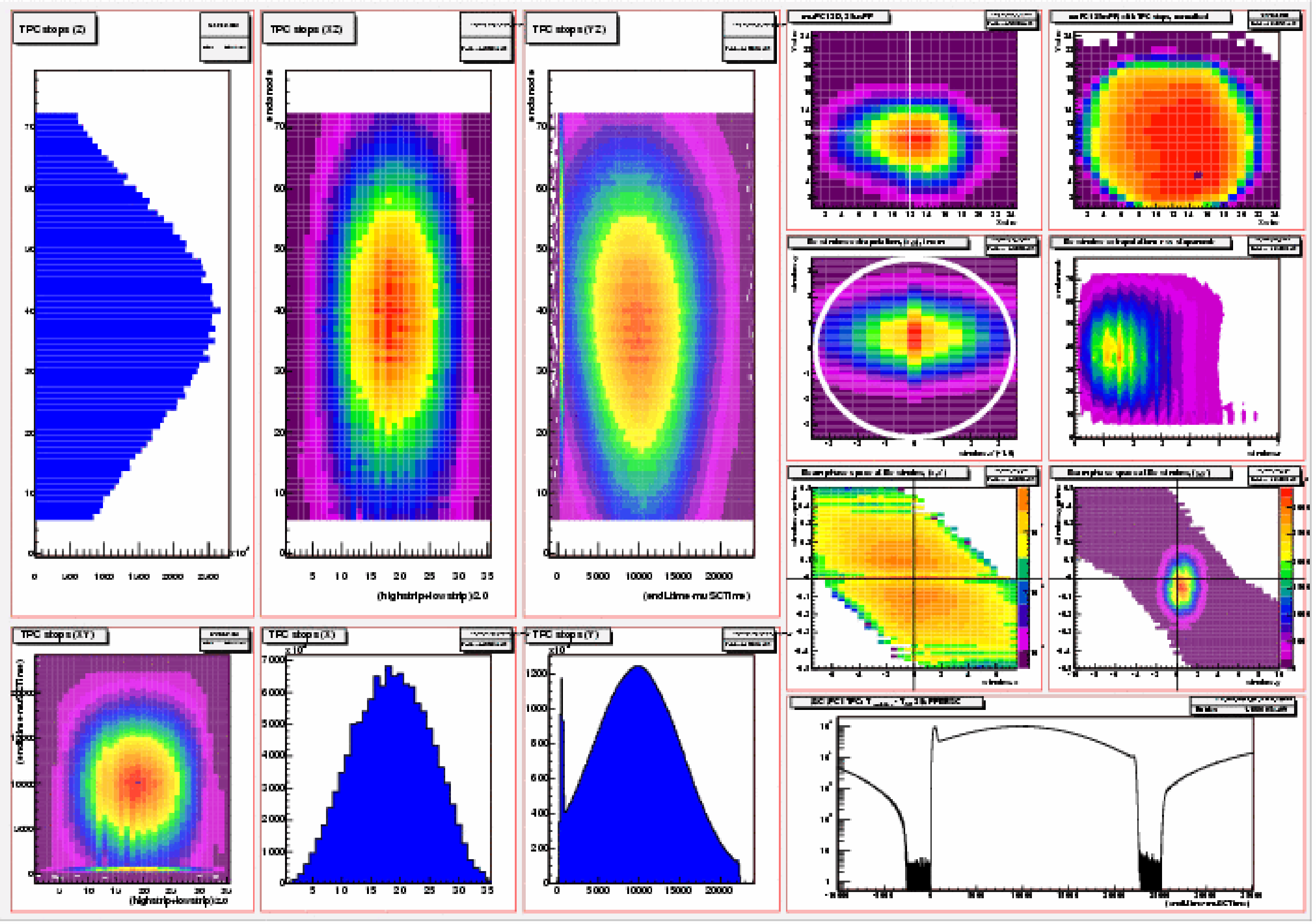


MBAS Muon Identification: Combined Detectors

A familiar image from the Run8 online display:



MBAS Electron Identification: ePC clustering

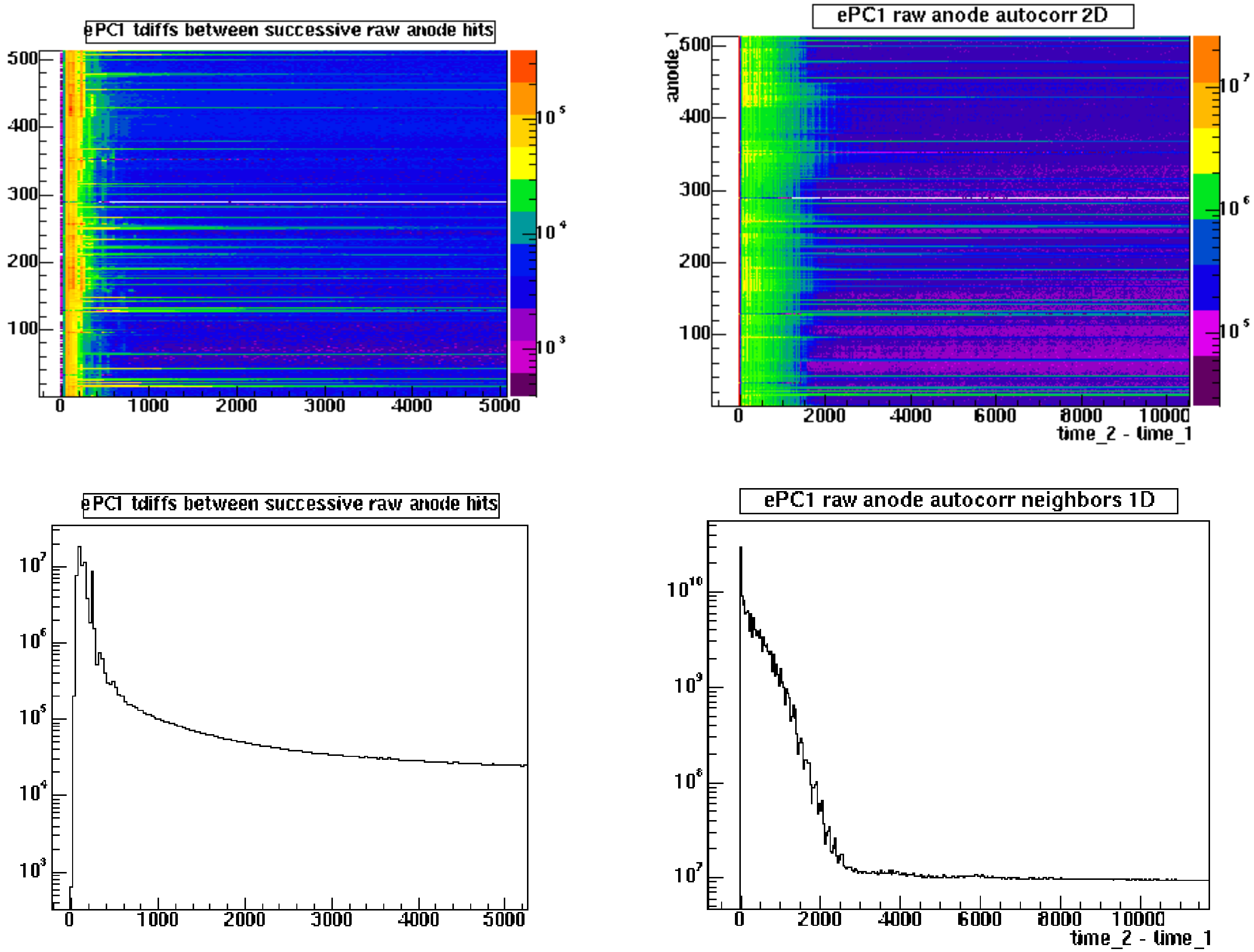
In order to identify electron hits, each ePC plane receives the following clustering treatment (also applied to the muPC1 and eSC raw data):

1. Inspect raw data
2. Perform spark cuts (SC)
3. Perform afterpulse clustering (AC) or enforce an artificial deadtime (AD) *per wire*
4. Perform final clustering *across* wires

MBAS Electron Identification: ePC clustering

To illustrate, let us look at how this sequence is applied to the ePC1 anodes:

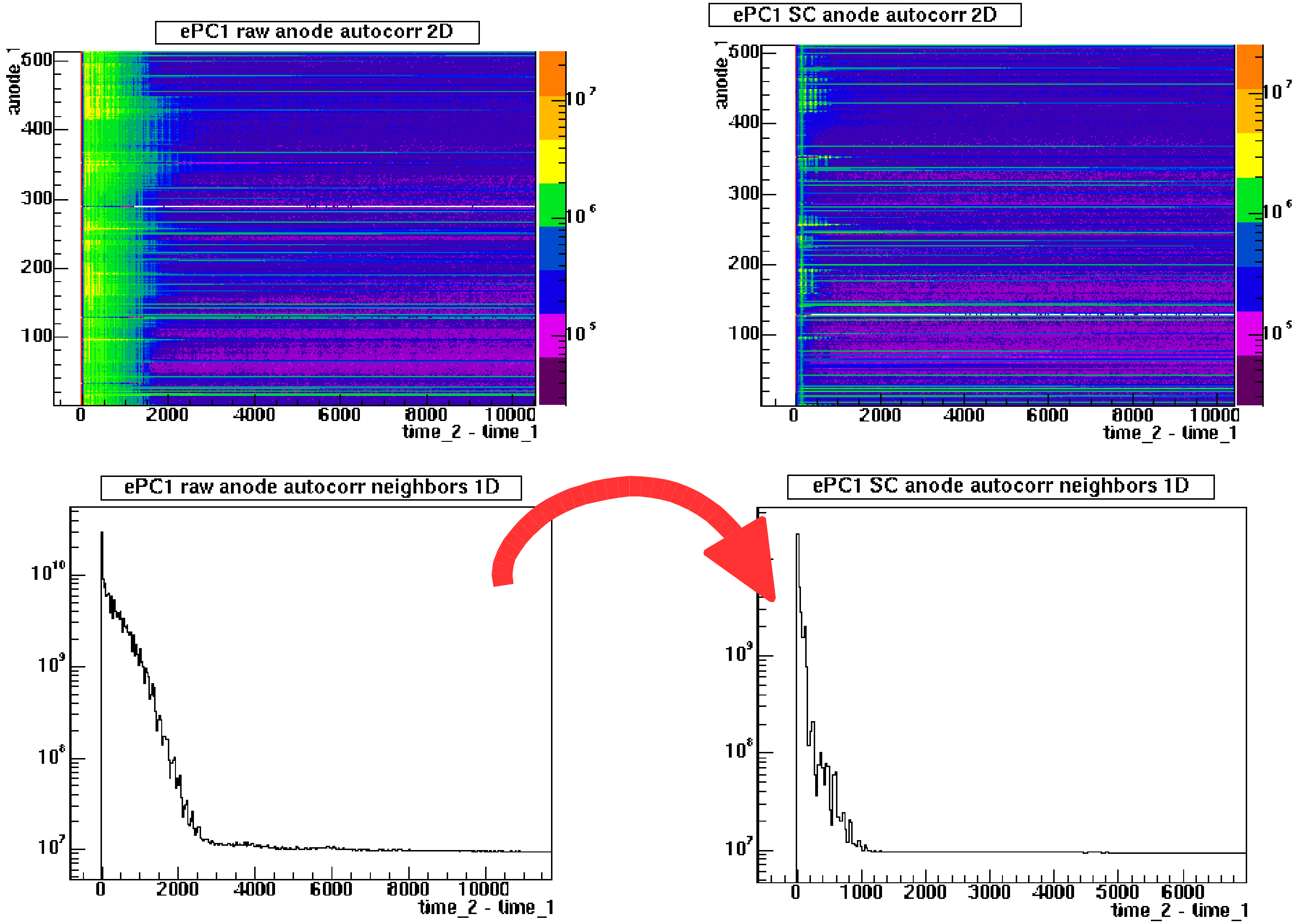
Step 1.
raw data



MBAS Electron Identification: ePC clustering

To illustrate, let us look at how this sequence is applied to the ePC1 anodes:

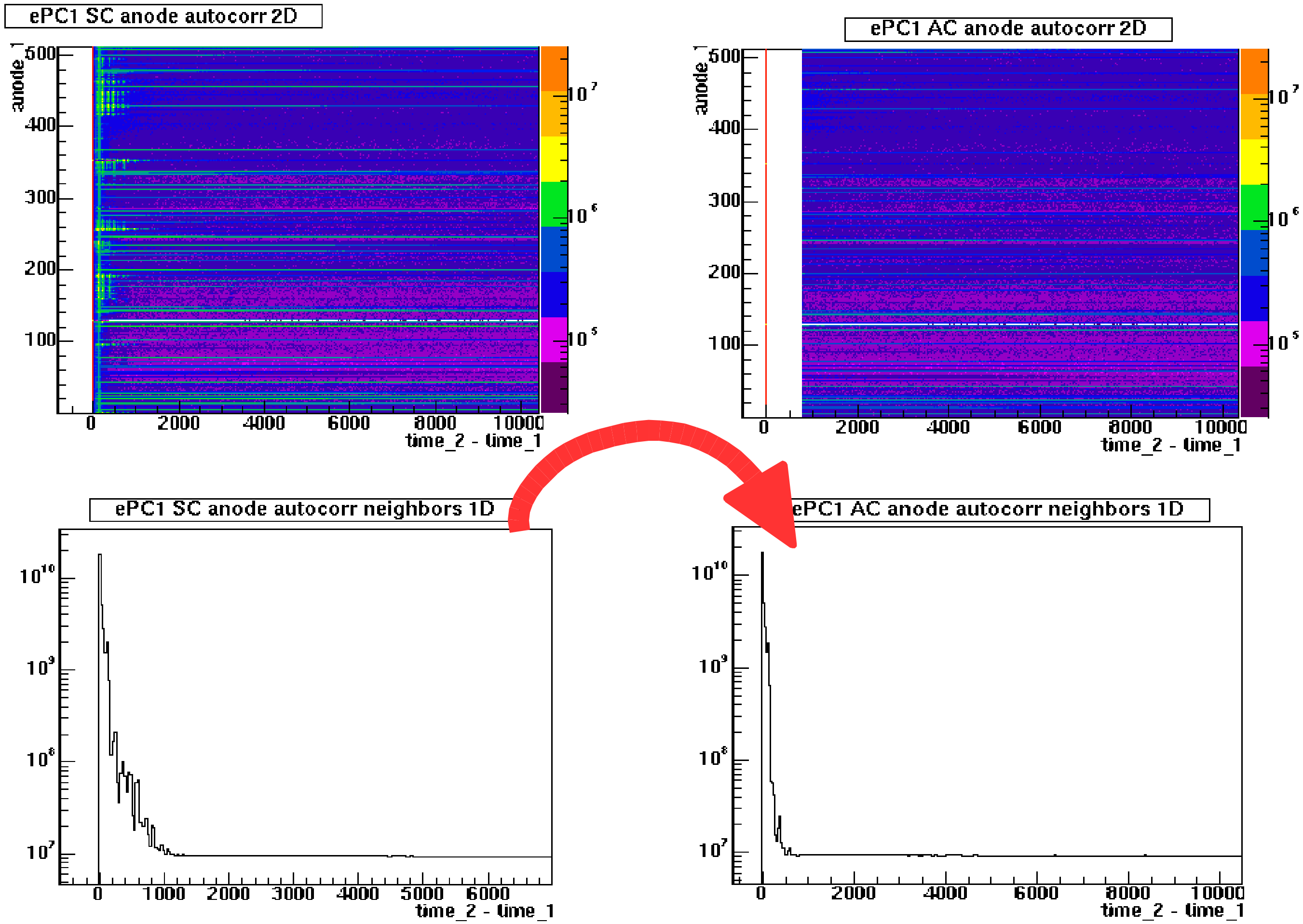
Step 2:
spark cuts



MBAS Electron Identification: ePC clustering

To illustrate, let us look at how this sequence is applied to the ePC1 anodes:

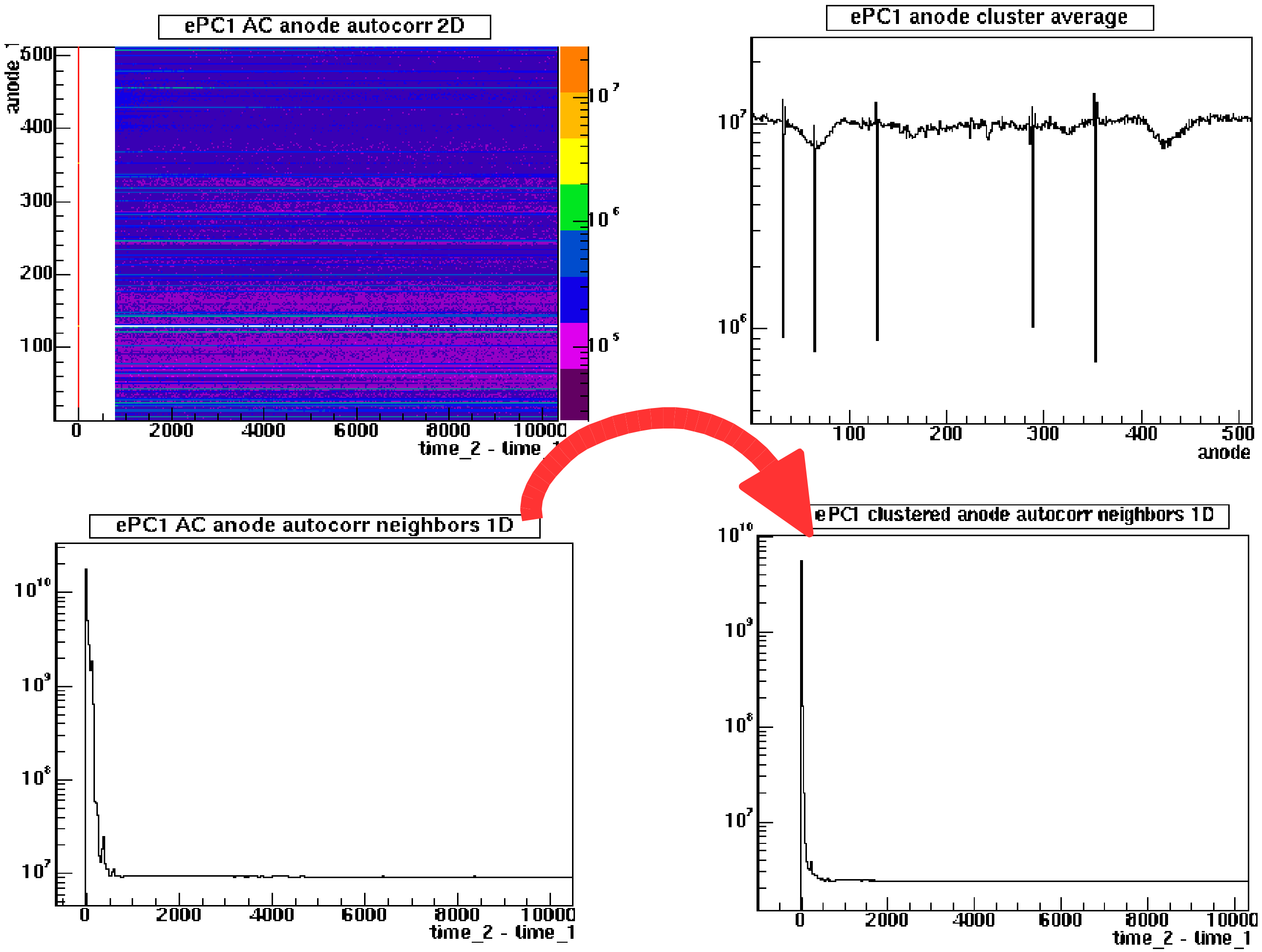
Step 3:
afterpulse-clustering



MBAS Electron Identification: ePC clustering

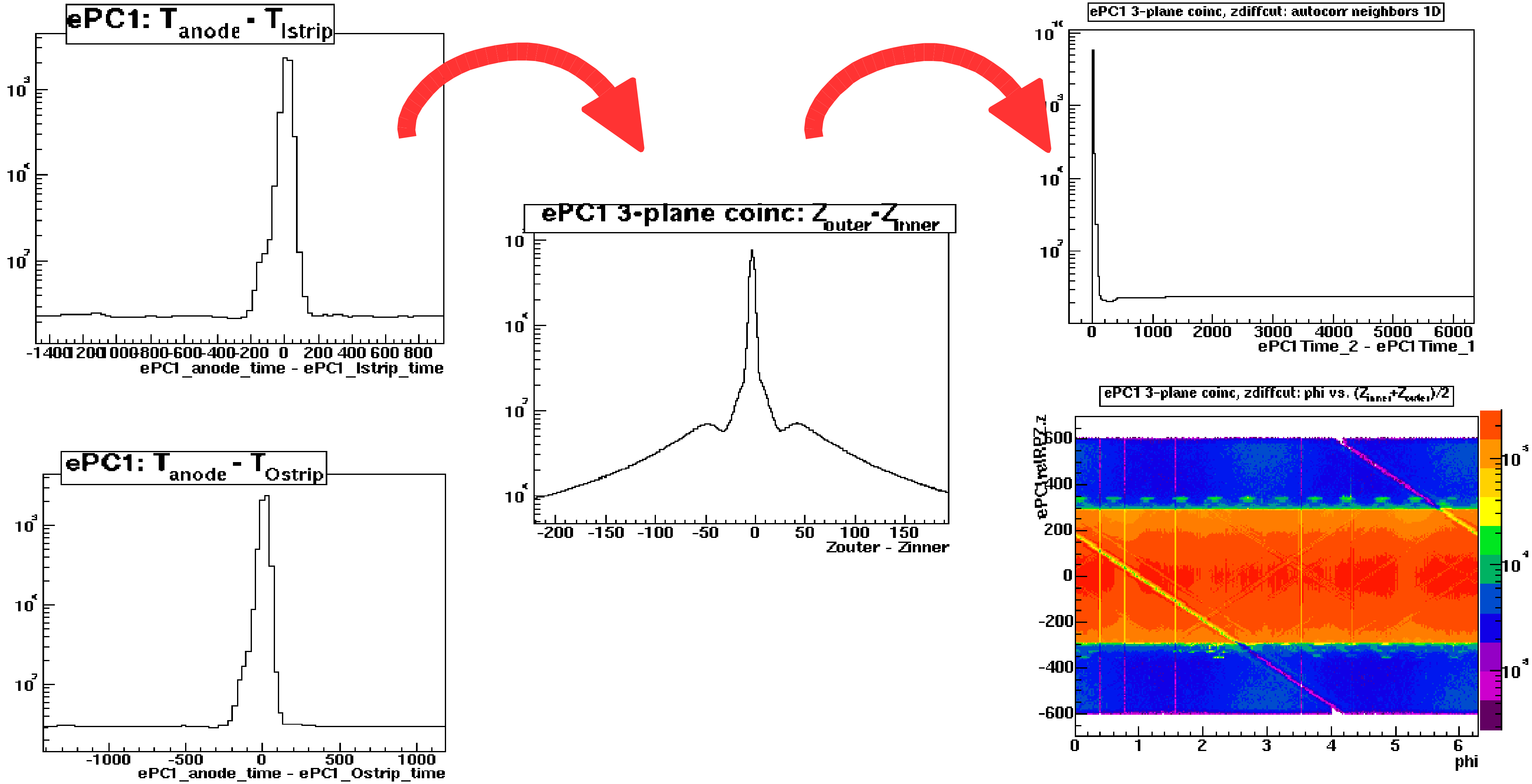
To illustrate, let us look at how this sequence is applied to the ePC1 anodes:

Step 4:
final clustering across wires



MBAS Electron Identification: ePC coincidences

Each ePC plane – anodes, inner strips, and outer strips – first undergoes the preceding clustering sequence. Then temporal anode/Istrip and anode/Ostrip coincidences are formed, the two sets are joined by common anode data, and a z-difference cut is applied for the final selection.



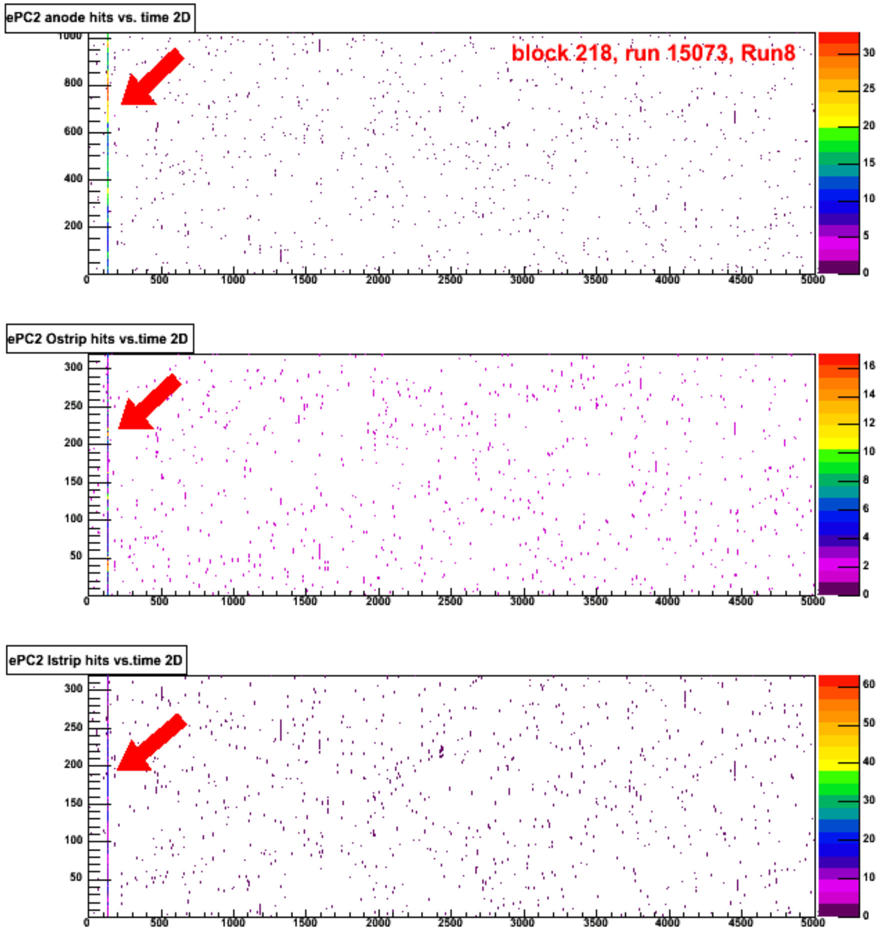
MBAS Electron Identification: ePCs

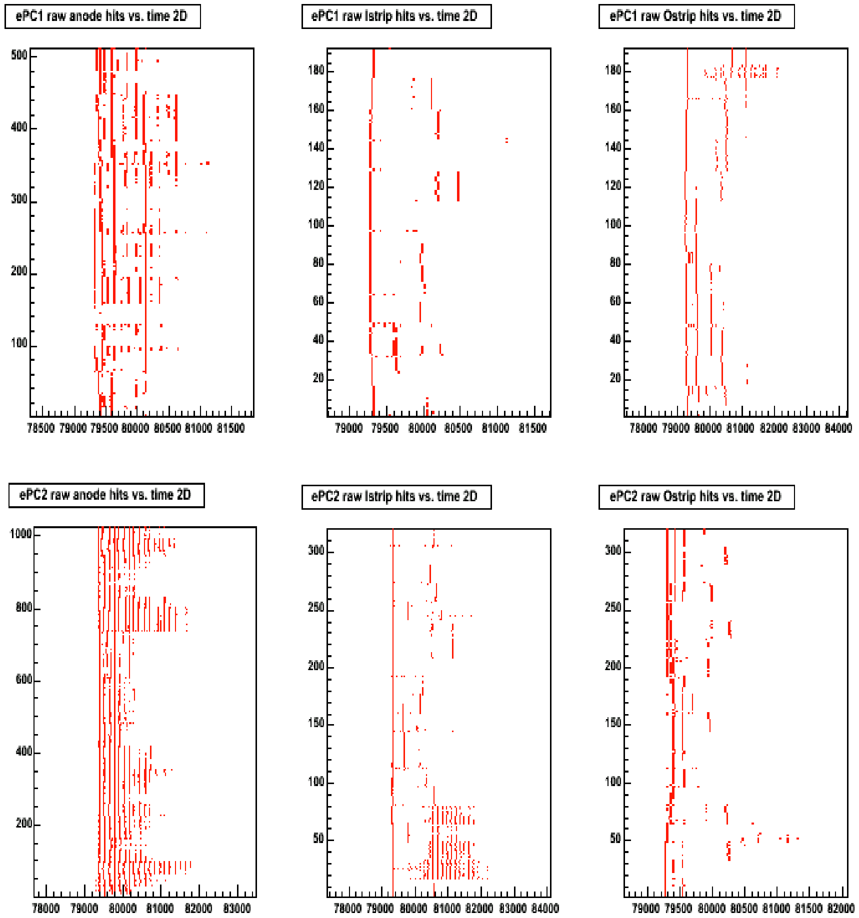
Several ePC banks containing different detector combinations are exported downstream, many for the purpose of calculating efficiencies:

- *Anodes (A)*
- *Inner strips (I)*
- *Outer strips (O)*
- *Anodes/Inner strips (AI)*
- *Anodes/Outer strips (AO)*
- *Inner/Outer strips (IO)*
- *3-plane (AIO)*
- *Sparks, all*
- *Sparks, chamberwide*

MBAS Spark Recognition: Global

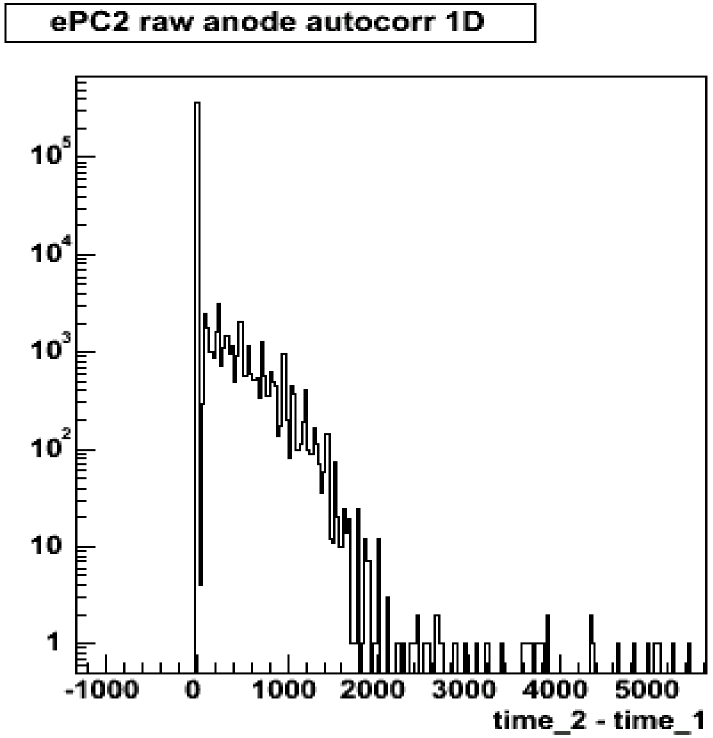
I identify “global”, or MuCap detector-wide, sparks by looking at the 6 ePC1 and ePC2 detector planes. Blocks containing global sparks are rejected in their entirety.

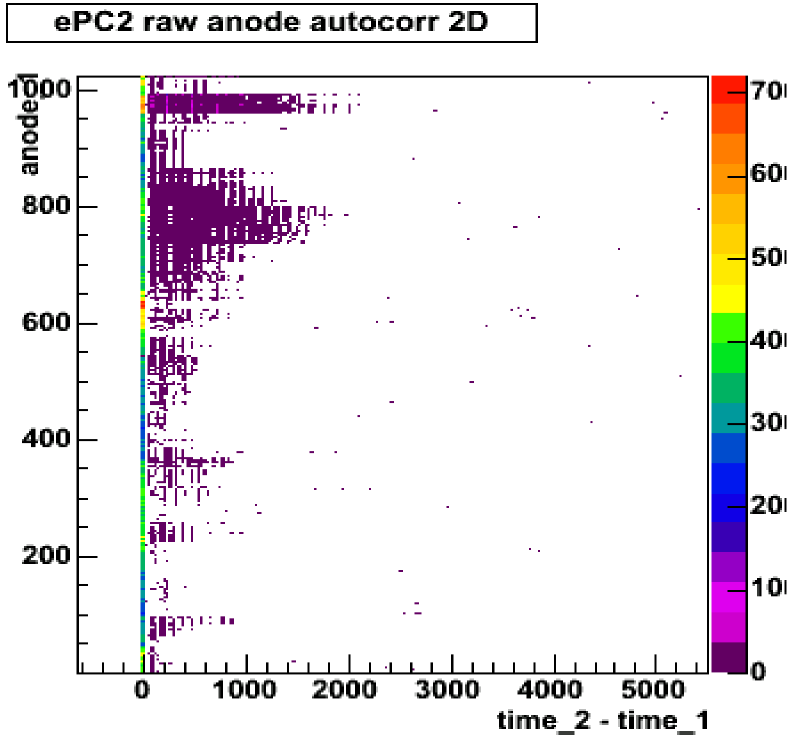




MBAS Spark Recognition: Local

However, just cutting global sparks isn't enough. The MWPCs will still suffer from “local” sparking, often in preamp card groups. For example, here are some ePC2 anode autocorrelation plots *after* global spark cuts:

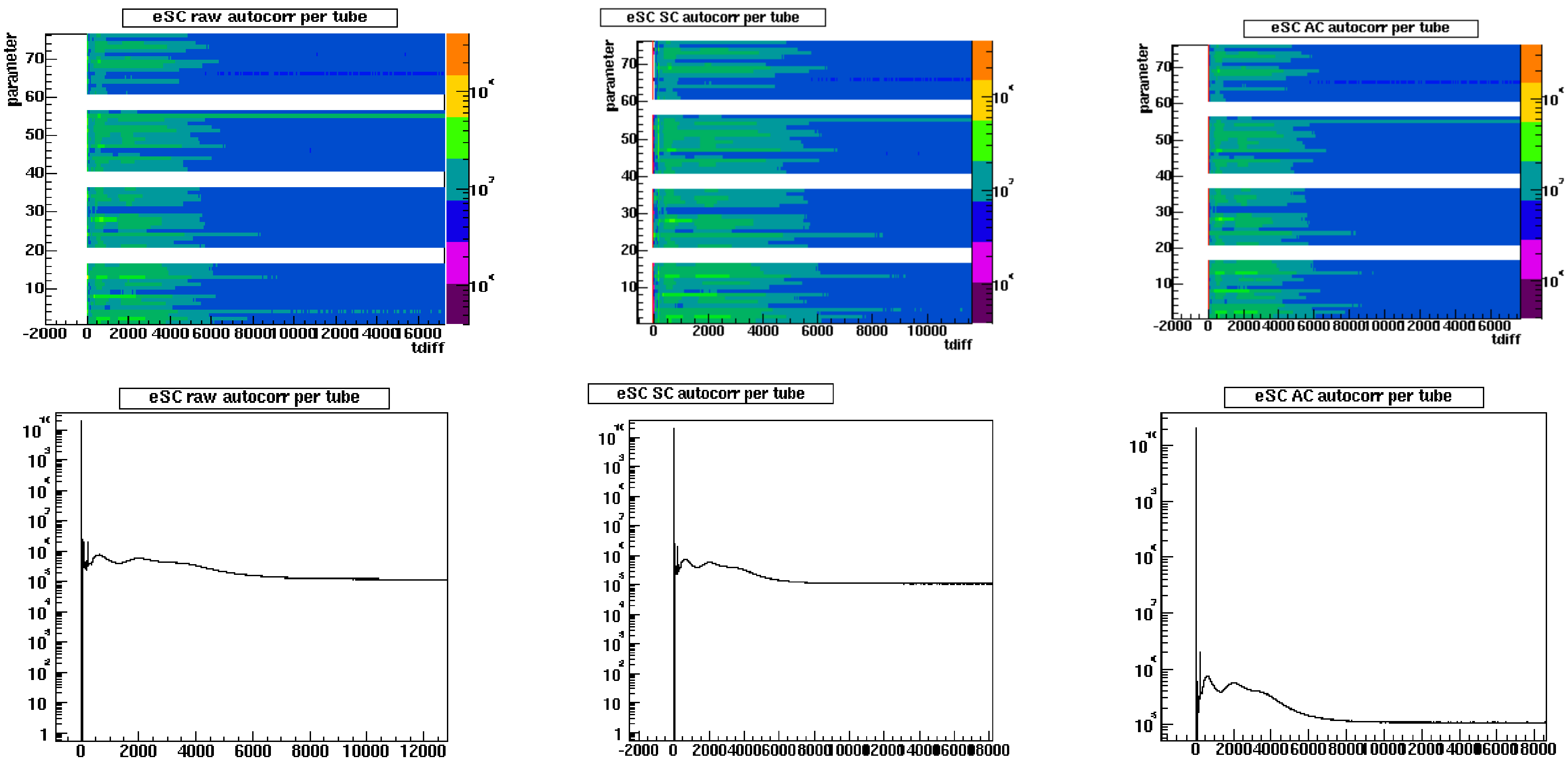




If the local spark clusters are big enough they are cut from the data. But there will inevitably still be some afterpulsing, even after spark cuts. Afterpulse-clustering prevents hot wires from biasing the cluster's spatial center-of-gravity.

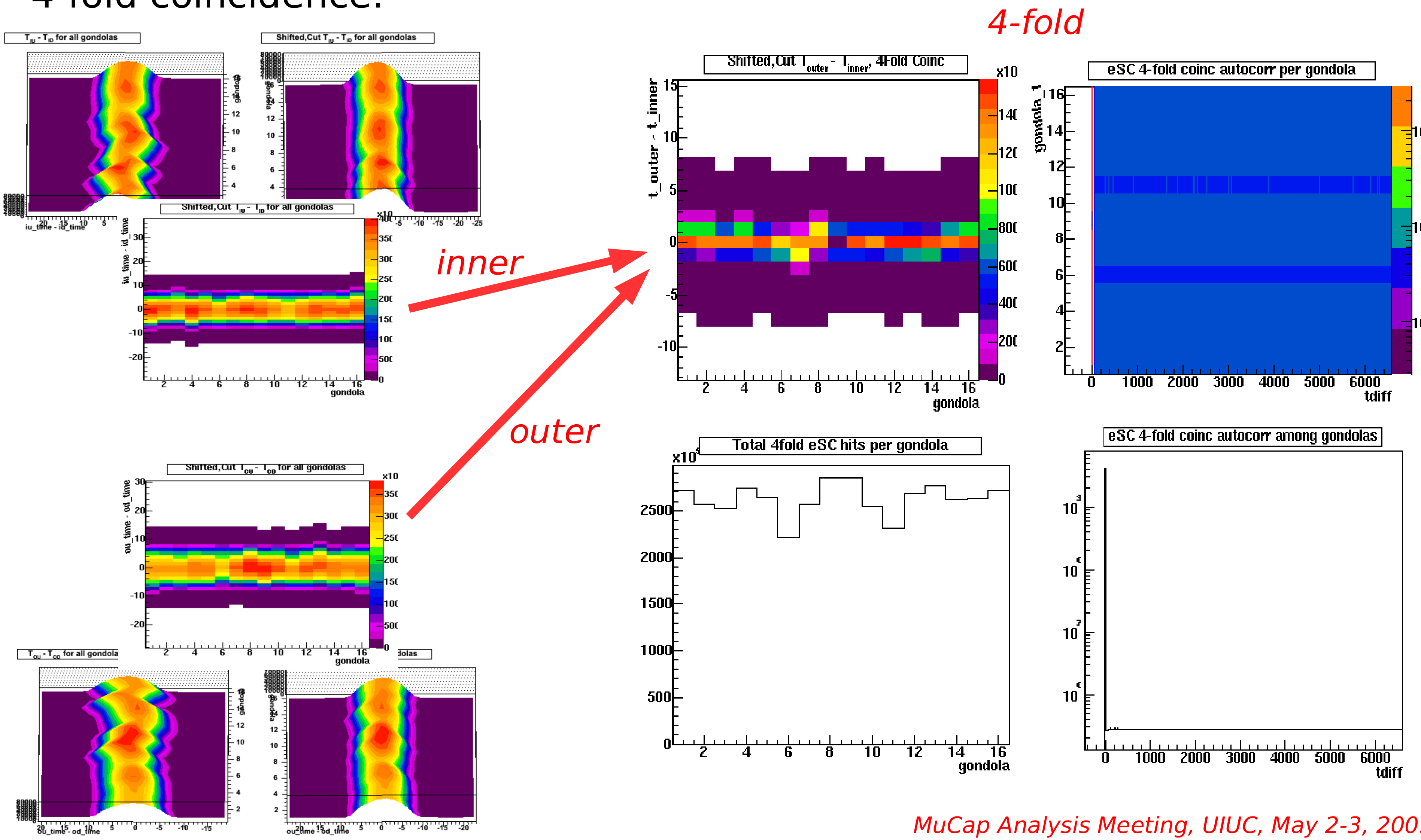
MBAS Electron Identification: eSC

The eSC raw data is processed in a manner similar to that just described for the ePCs, except that of course there is no final clustering across gondolas. Effects appear to be less pronounced for the eSC data.



MBAS Electron Identification: eSC

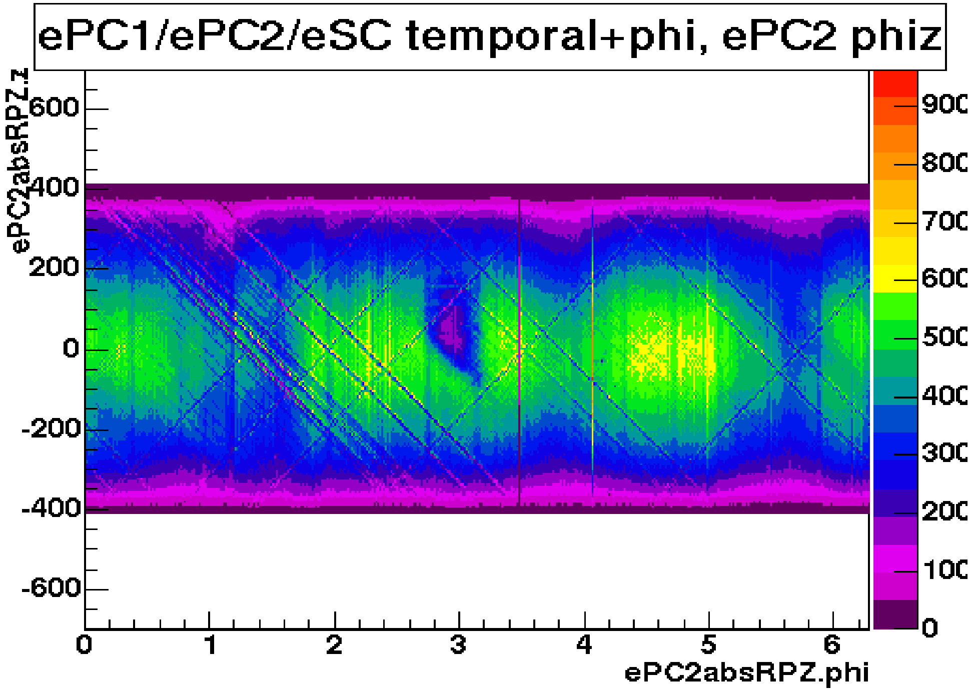
After the raw data preprocessing, the inner and outer gondola coincidences are formed separately, then joined together for the final 4-fold coincidence:



MBAS Electron Identification: Combined Detectors

There are innumerable ePC/eSC detector plane combinations possible, but they all currently use only temporal and phi-spatial coincidence criteria – no z.

For the ePC1/ePC2/eSC all-detector combination, I track the ePC1/ePC2 vector to the eSC plane, and perform a (t,phi) cut upon that coincidence.



MBAS Muon/Electron Selection: “Approval” Process

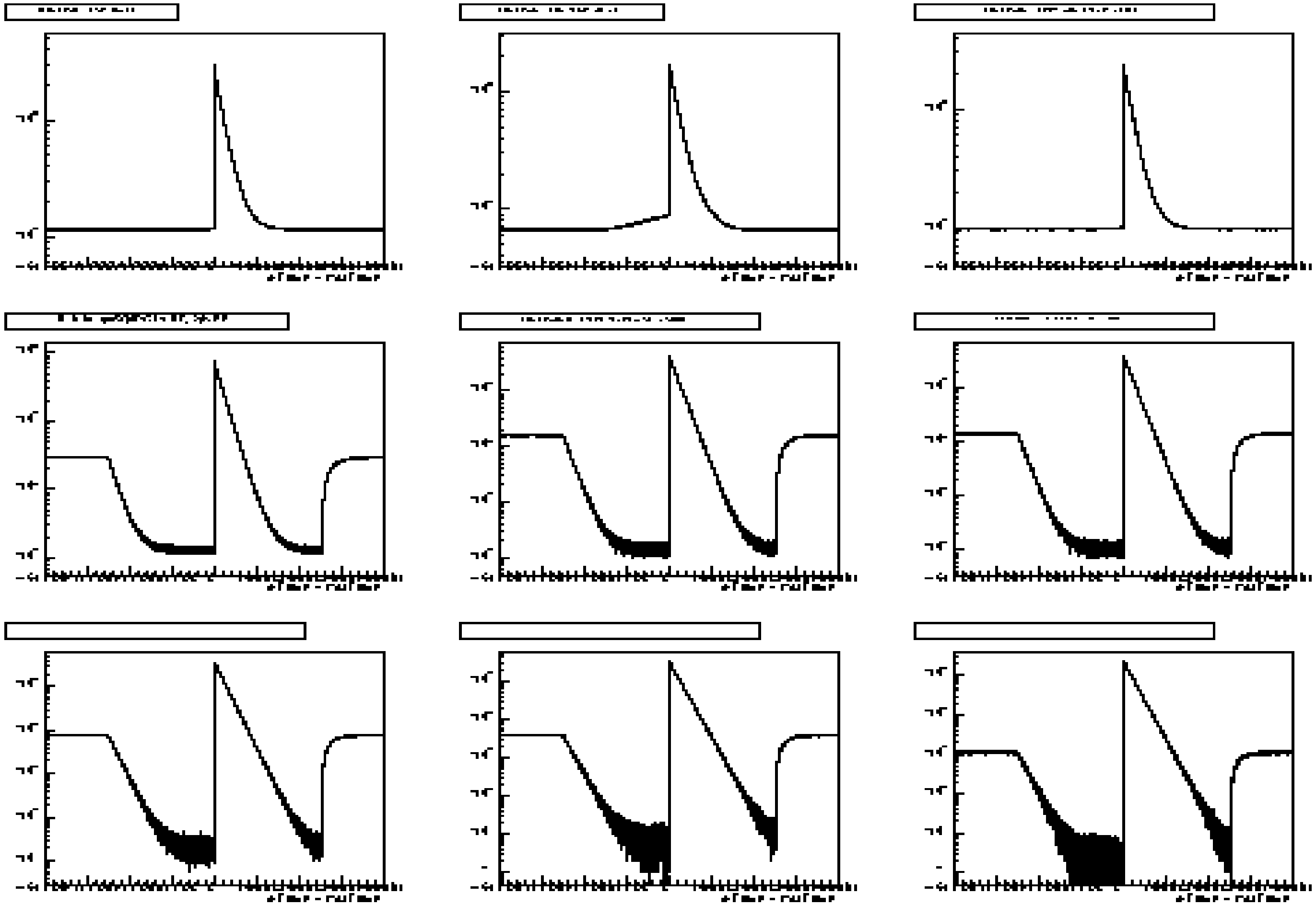
For the final muon and electron selection, I use an “approval” approach towards multi-detector coincidences. That is, after I form a set of coincidences—say, ePC1/ePC2/eSC—but before I create any lifetime histograms, I eliminate combinatoric ambiguities in the data set. I consider the ePC hits to have “approved” the eSC hits, and I reduce the ePC1/ePC2/eSC data set down to a unique set of eSC hits, thereby eliminating multiplicities without making any choices among the different possible reconstructions.

The muon and electron data sets used for the lifetime histograms contain only unique entries, and so each lifetime entry (mu/e coincidence) is also unique.

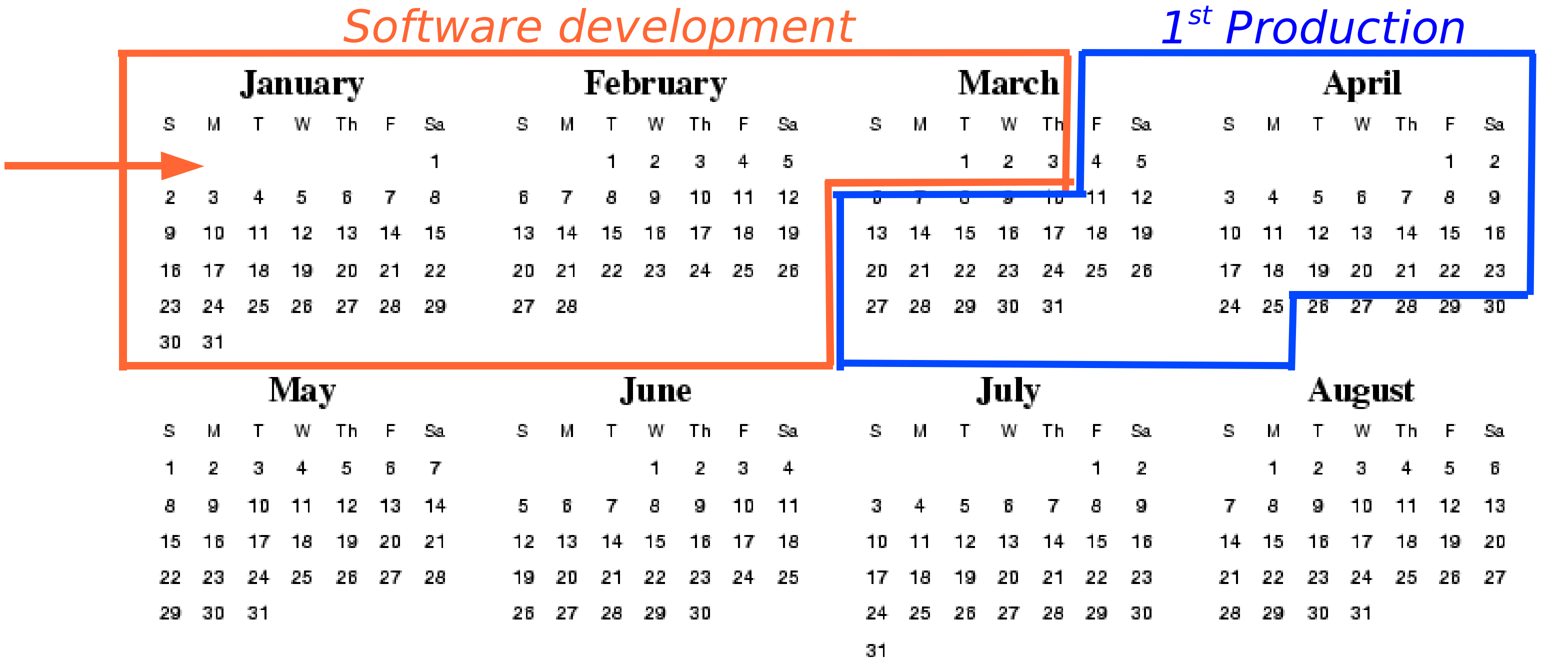
(Sorry there's no picture here. I can't think of how to draw this.)

MBAS Lifetime Histograms

And finally, we can form all sorts of lifetime histograms from various combinations of the different reduced muon and electron data sets:



Analysis Progress in 2005



- The MBAS was under intense development from November 2004 through March 2005.
- The first production pass over the entire Run8 data set recently finished, and the output (in run subgroups) is available at:

merlin.psi.ch:/data/disk4/mucap/run8_pass0_sums

Analysis Results: Block Cuts/Rejections

From the pass0 “Prod50” mu– summed ROOT files:

Total blocks analyzed (accepted).................7,125,653

Block cuts

- *block duplication*..9,971 ~ 0.1%
- *CAEN error*..35,071 ~ 0.4%
- *CAEN rollover error*.....................................12,847 ~ 0.2%
- *COMP error*...264 ~ 0%
- *TDC400 error*..8,905 ~ 0.1%
- *muSC matching error*.................................16,959 ~ 0.2%
- *eSC CAEN only*..11,087 ~ 0.2%
- *eSC COMP only*..35,879 ~ 0.4%
- *global sparks*...20,064 ~ 0.3%

→ Roughly 2% total block cuts

Analysis Results: Muon Statistics

From the pass0 “Prod50” mu– summed ROOT files:

- *muSC raw*...18,375,414,004
- *muSC BE*...18,148,351,922
- *muSC BESC*..18,146,583,011
- *muSC 25usPP*..5,754,502,222
- *muSC/muSCA*..17,925,790,945
- *muSC/muSCA 25PPBESC*.............................5,748,665,109
- *muSC/muSCA/muPC1 25PPBESC*...................5,191,293,724
- *muSC/muSCA/muPC1/TPC 25PPBESC*............3,289,554,215
- *muSC/muSCA/muPC1/fidTPC 25PPBESC.........3,052,337,171*
- *muon decay estimate*.................................1,897,487,241

Analysis Results: Electron Statistics

From the pass0 “Prod50” mu– summed ROOT files:

- *(ePC1/)eSC*................10,558,483,290
- *(ePC2/)eSC*................10,073,331,229
- *eSC 4-fold*..................11,416,483,715
- *(ePC1/ePC2/)eSC*.........9,527,838,987

We know that the eDetectors have 75.9% solid angle coverage (the eSC is the limiting detector), and Steve's efficiency studies indicate that the eSC gondolas have a 97% efficiency.

ePC1 Efficiencies

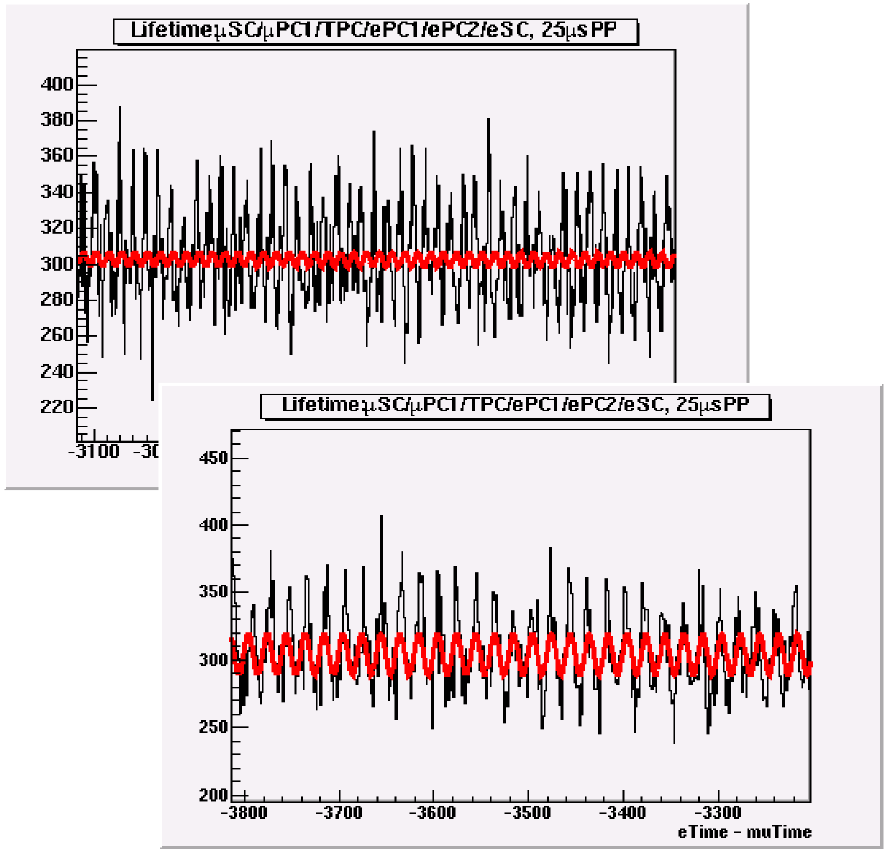
93.8 % ..... Anodes (A)
94.7 % ..... Istrips (I)
93.7 % ..... Ostrips (O)
93.6 % ..... AI
92.7 % ..... AO
93.6 % ..... IO
92.5 % ..... AIO

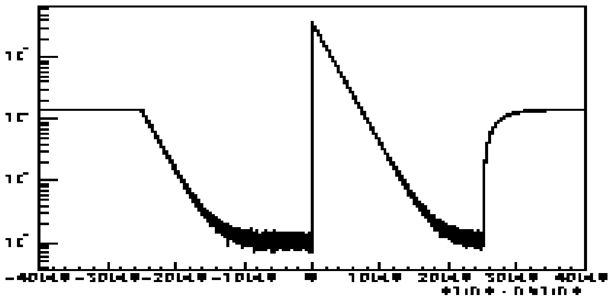
ePC2 Efficiencies

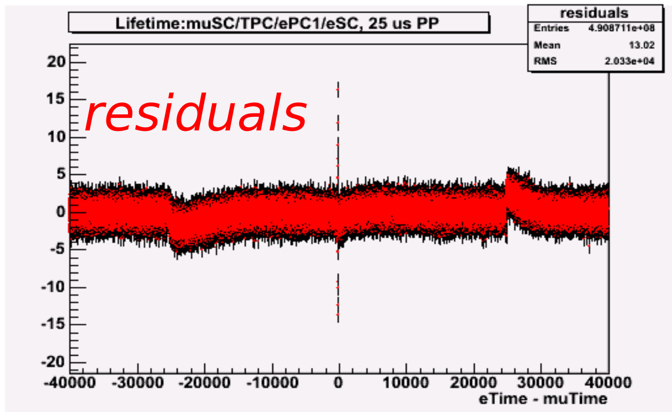
94.1 % ..... Anodes (A)
92.8 % ..... Istrips (I)
89.9 % ..... Ostrips (O)
91.6 % ..... AI
88.9 % ..... AO
89.4 % ..... IO
88.2 % ..... AIO

Analysis Results: Lifetime Fitting

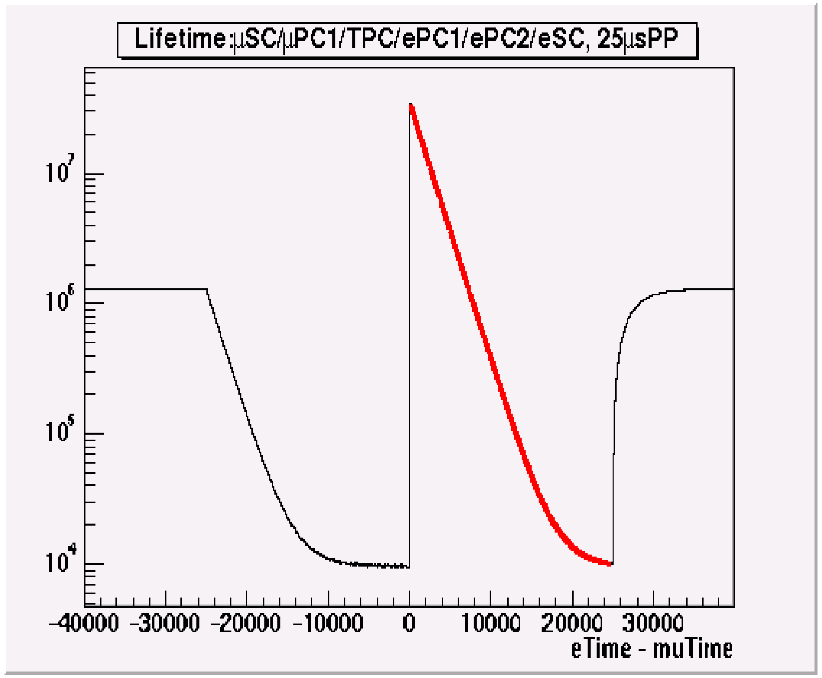
So far I have only worked with mu- lifetime histogams (Fred has spent some time on mu+ analysis). The 50 MHz background has proved difficult to fit, and the shape of the PP background (at least in mu-) is not a simple exponential. This suggests we should (1) rebin the histograms to eliminate the 50 MHz RF, and (2) fit only over the approximate range 0 – 25 microseconds.





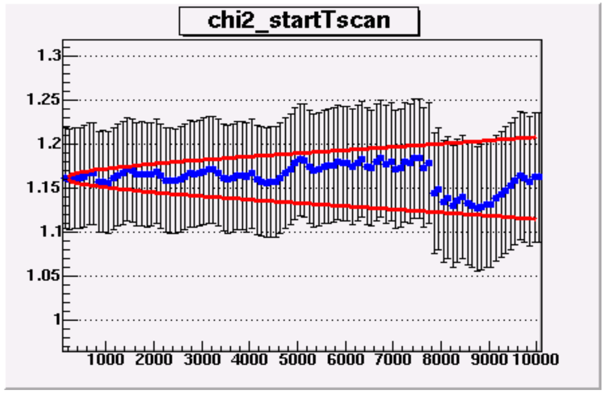


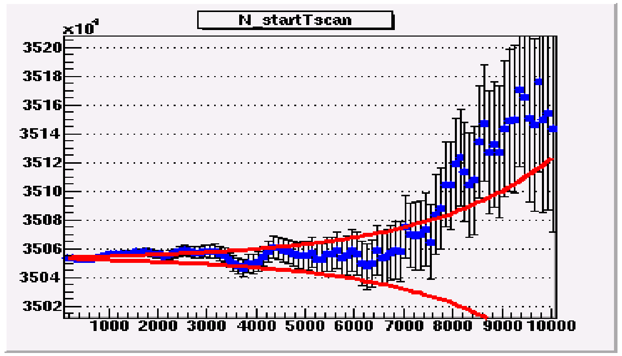
Analysis Results: Lifetime Fitting

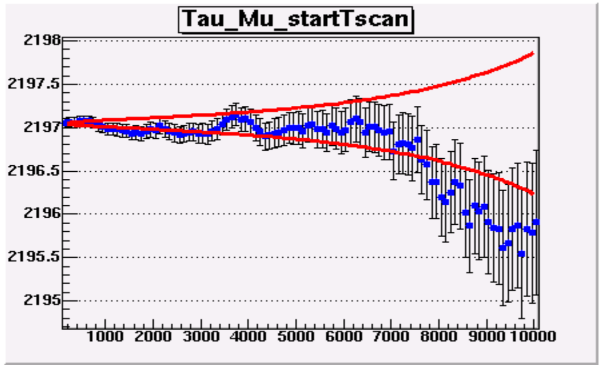


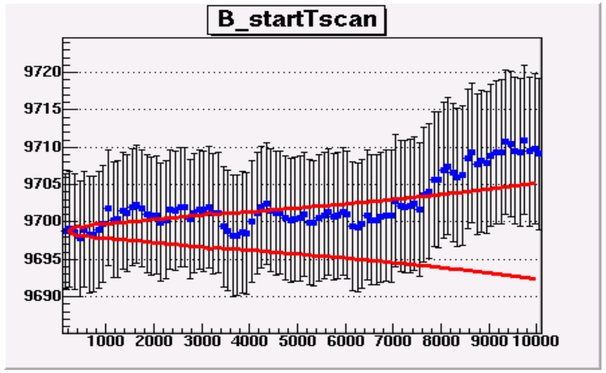
Here are some cursory fit results to the latest pass0 *prod50* mu– data, using the simple 3-parameter function

$$f(t) = B + N \bullet exp(-t/Tau)$$



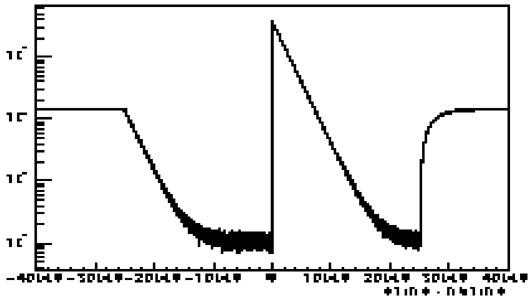






Analysis Results: Lifetime Fitting

List of potential lifetime fit studies:



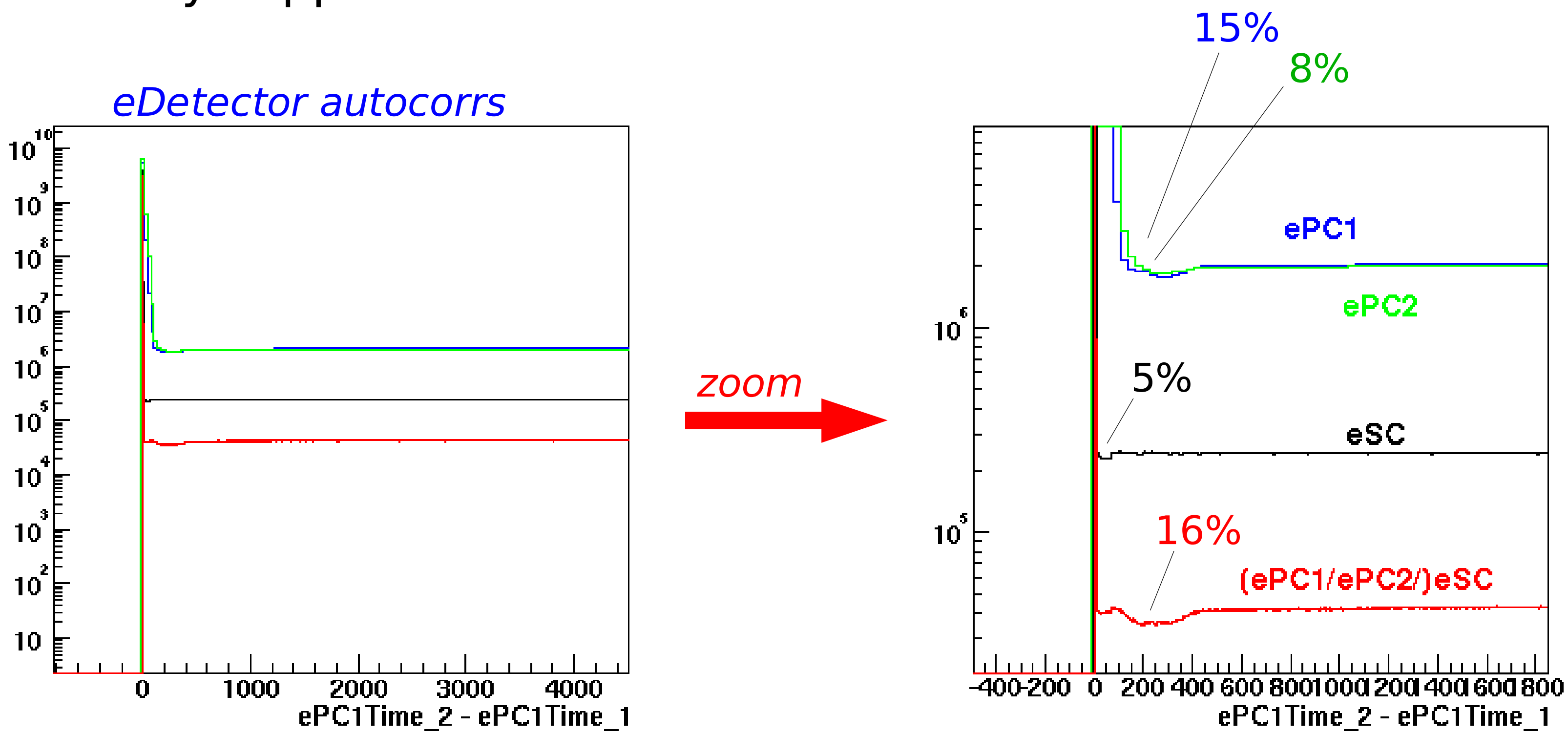
- vs. different fit functional forms
- vs. different fit ranges (vary start/stop times)
- vs. different rebinnings
- vs. different detector combinations
- vs. different detector signals (e.g. eSC's CAEN/COMP signals)
- vs. run groups (when do “clean” runs begin after CHUPS turn-on?)
- vs. time (early/late Run8, day/night, etc.)
- vs. detector regions (e.g. fiducial TPC, eSC forward/backward)
- vs. muon type (mu-/+)
- vs. deuterium concentration
- vs. impurity concentration
- vs. gondola
- vs. different impact parameter cuts
- vs. run conditions/slow-control parameters:
  - TPC high voltage/thresholds (see Francoise's work)
  - ePC high voltage
  - magnet conditions
  - old/new muSC detectors (changed ~ October 14, 2004)
  - CHUPS conditions
  - beam rate (or no beam at all)

Remaining (Analysis-Specific) Problems

- Effects from real and artificial detector deadtimes (esp. ePCs)
- Sympathetic decay electron showers
- TPC drift distribution treatment
- ePC2 inefficiency spots
- Study rate effects, efficiency variations w/time and position, etc.

Remaining Problems: Detector Deadtimes

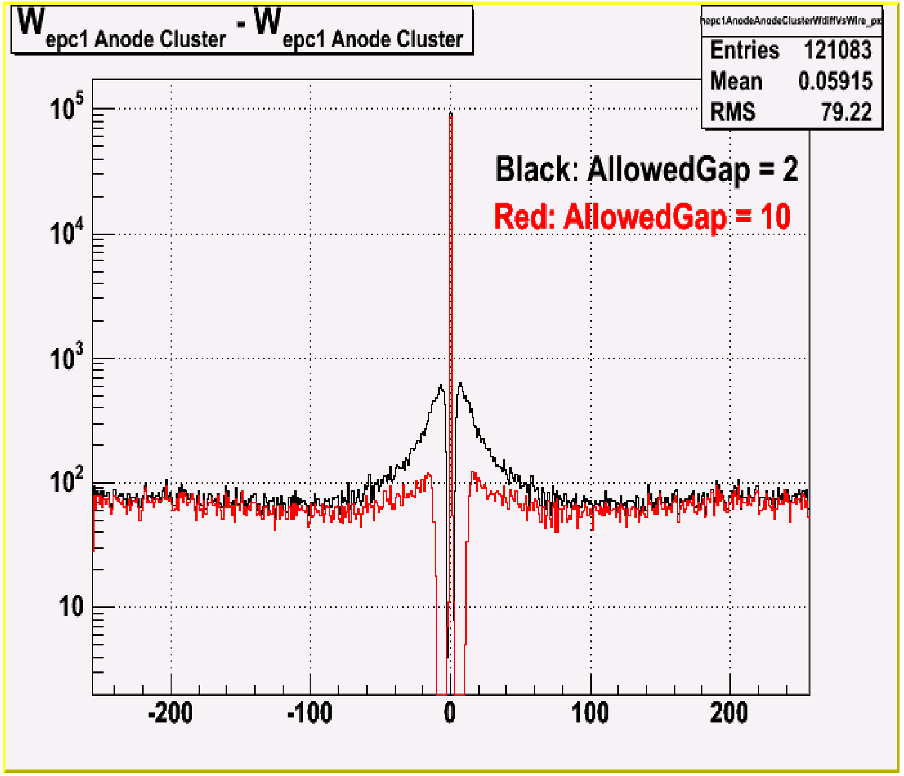
In order to suppress spark and afterpulsing noise – especially in the MWPCs – the MBAS utilizes both afterpulse-clustering (AC) and artificial deadtimes (AD), or “updating” and “non-updating” deadtimes, respectively. This raises concerns about possible effects on the lifetime, since some of the ePC planes receive lengthy (~ 1 microsecond) deadtime intervals. What is the depth and breadth of the deadtimes' efficiency suppressions?

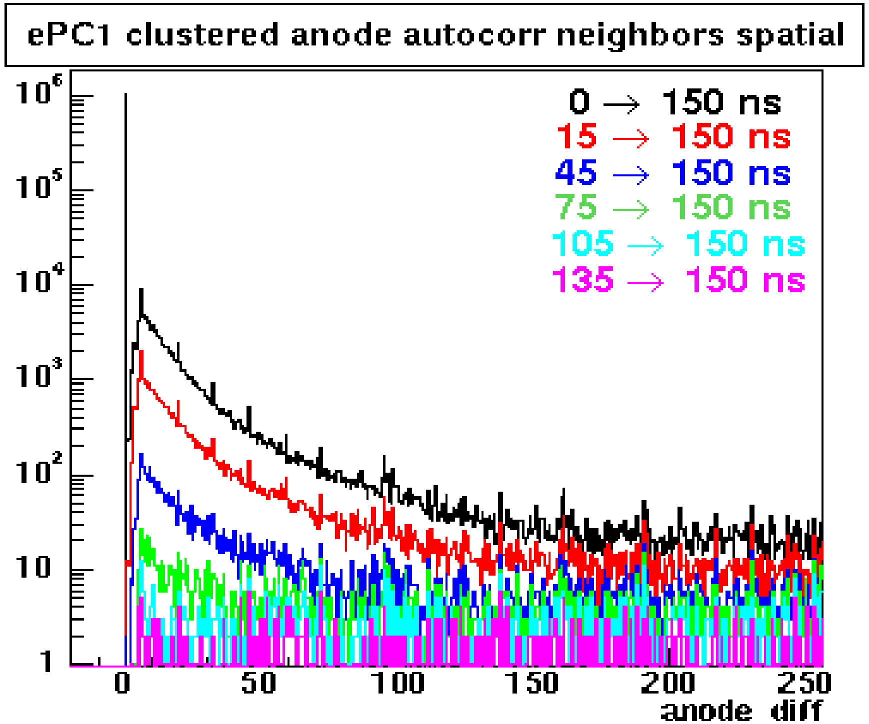


Remaining Problems: Decay Electron Showers

We see a nonuniform background in the ePCs' post-clustering spatial autocorrelation plots... is it physical or electronic? It shows up with and without beam; see Steve's analysis at

http://www.npl.uiuc.edu/exp/mucapture/coll/mucap/smclayto/ElectronDetectorResponse/edet_response.html

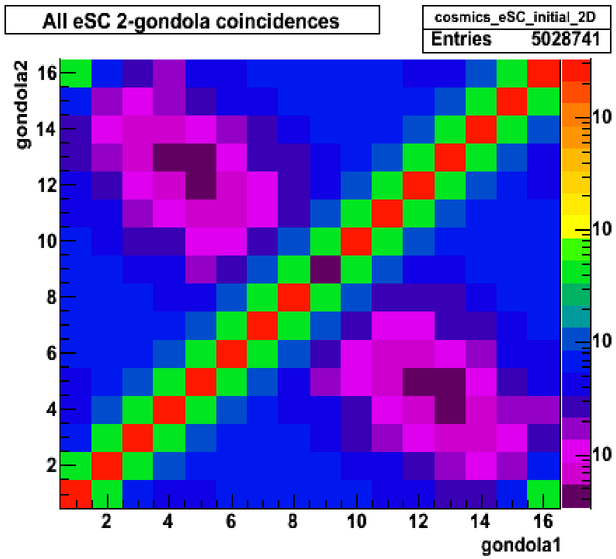




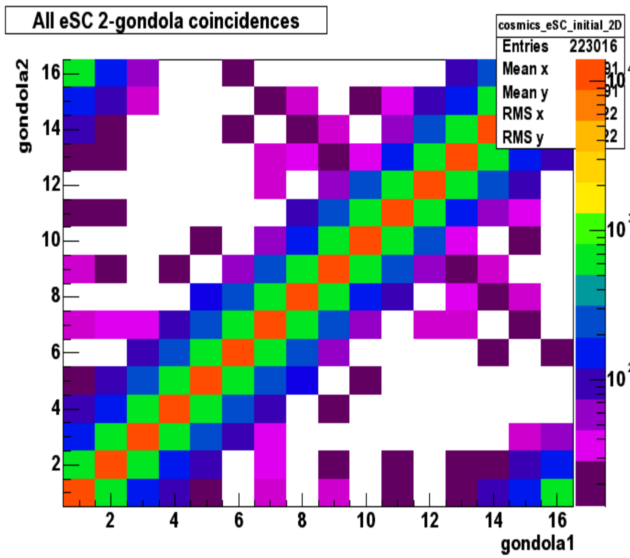
Remaining Problems: Decay Electron Showers

Could so-called “delta electrons” be responsible? (See Peter's entry on delta electrons in Run8-Analysis ELOG 37.) Bernhard's MC results suggest they might be to blame...

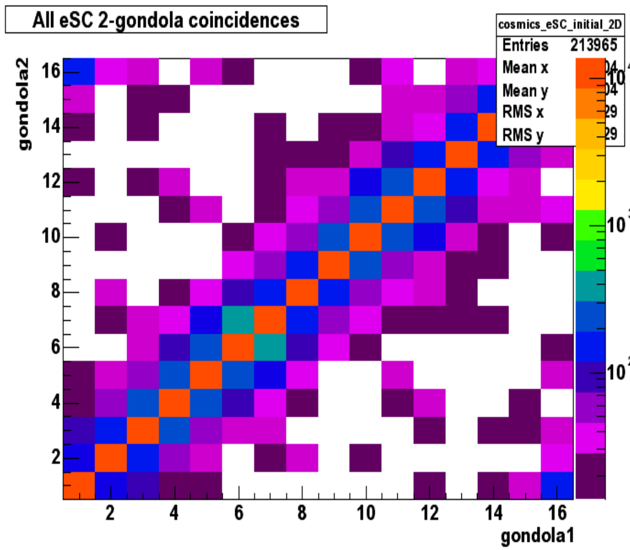
Run8 data



Bernhard's MC results with delta electrons turned “on”



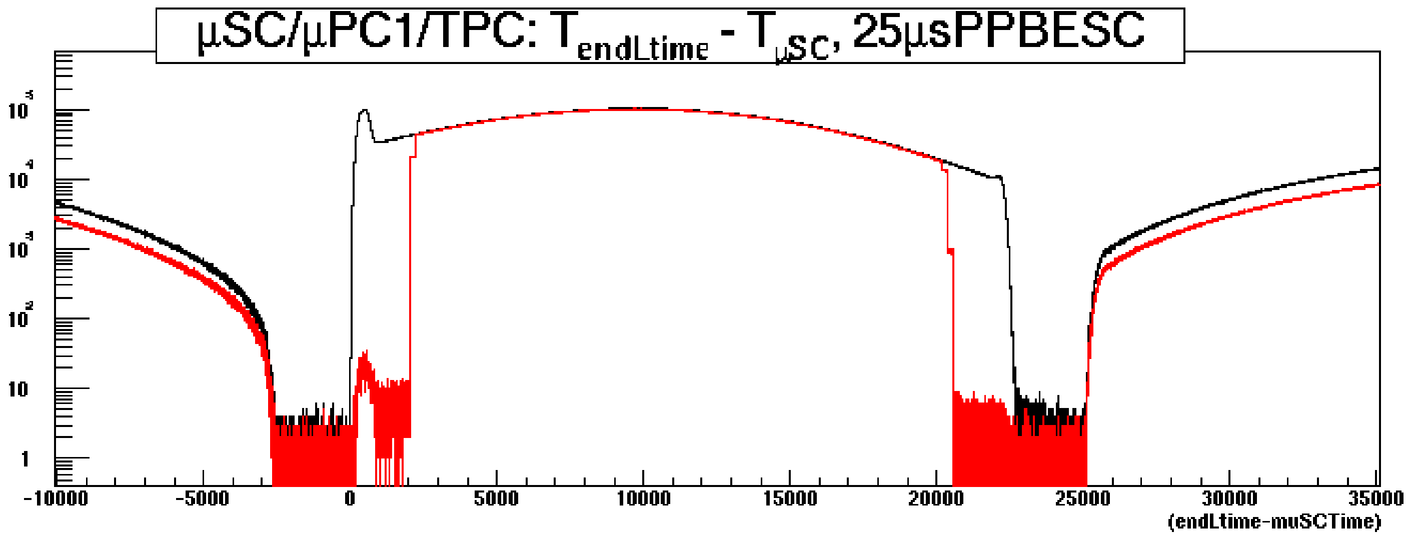
Bernhard's MC results with delta electrons turned “off”



Or are these knock-off electrons? If so, what do we do? How do these affect the muon lifetime histogram?

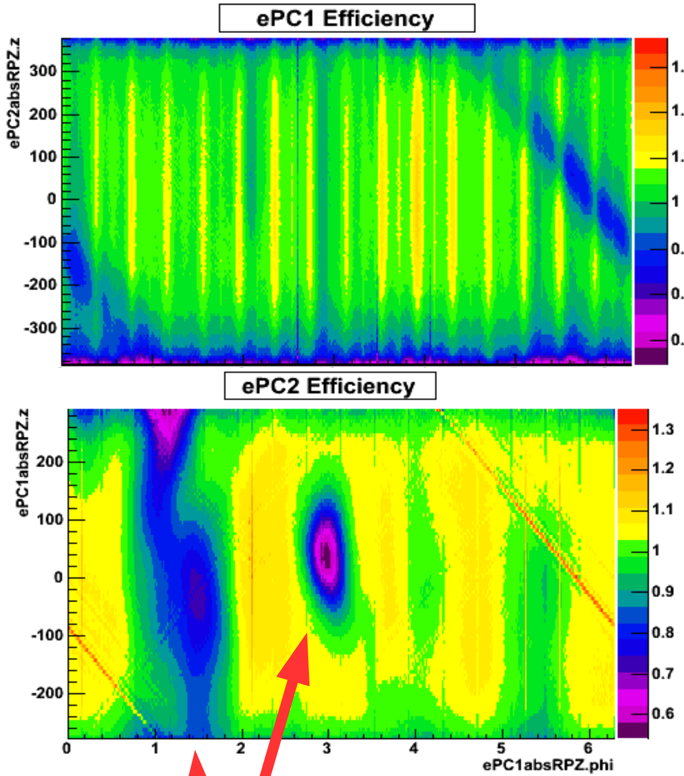
Remaining Problems: TPC Drift Distribution

- Were there drift field variations during Run8? (Yes, some)
- Are the drift distribution's features well-understood? (Not entirely)
- Is time / y-position relationship uniform along the drift length?
  Especially important for fiducial volume and impact parameter cuts.
- What *is* a good fiducial volume? I've used a 8 mm buffer from edges,
  but Technical Proposal (p.41) recommends 1.5 cm.

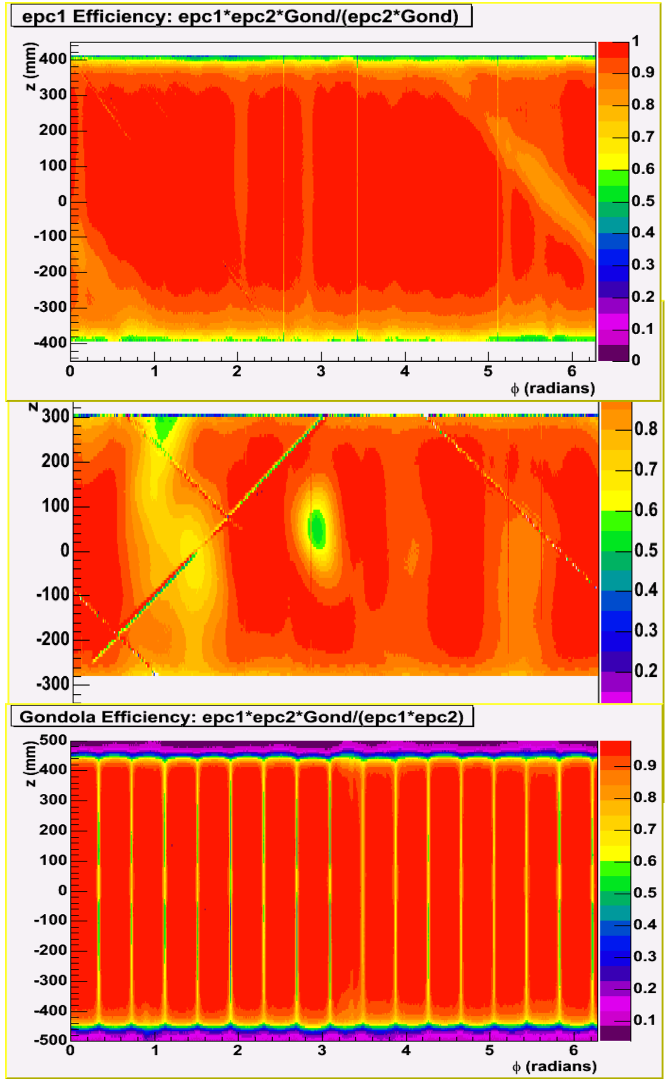


Remaining Problems: ePC2 Inefficiency Spots

Tom's Plots



Steve's Plots



We see some inefficiency spots in the ePC2 (phi,z) distribution, uncorrelated with any single plane. There's nothing we can do about it, but it's worth mentioning.

Potential Analysis Improvements

- Shortcuts to speed up processing? (e.g. fill costly autocorrelation histograms on data subsets only; PP-limited TPC track sniffing)
- Mask hot wires on run-by-run basis? (to reduce ePC deadtimes) Cut bad runs?
- TPC pileup protection to eliminate muon matching ambiguities?
- Shorten the current PP interval (25 us) to something closer to the TPC drifttime (~ 23 us) ?
- Use Steve's event display to check MBAS events?
- Use eSC z-resolution in eDetector cuts?
- Cosmics: use for alignment and/or remove from electron data sets?
- Plot mu+ lifetimes for different TPC subvolumes, and look for variations due to inhomogeneity of the B-field?

Analysis Outlook

Daunting. There's a ***lot*** of work to do, and a many of the systematics issues are poorly understood, as we will discuss in upcoming presentations.

> *"It is essential to bring ideas to paper… many issues are intellectual challenges. [We] need focus." – P. Kammel*

We need to candidly discuss our timetable. Should we divide up some of the labor for the sake of expediency? What degree of thoroughness is acceptable for a first result? Should we investigate the previously enumerated items only as problems arise? In my opinion, it will be impossible to complete an exhaustive treatment within our accelerated timeline. We should establish priorities and limit ourselves to attacking the problems of most concern, and just make sure that there's no indication of egregious effects from the lesser topics.