Front end analog resolution for strip detectors

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Documentation

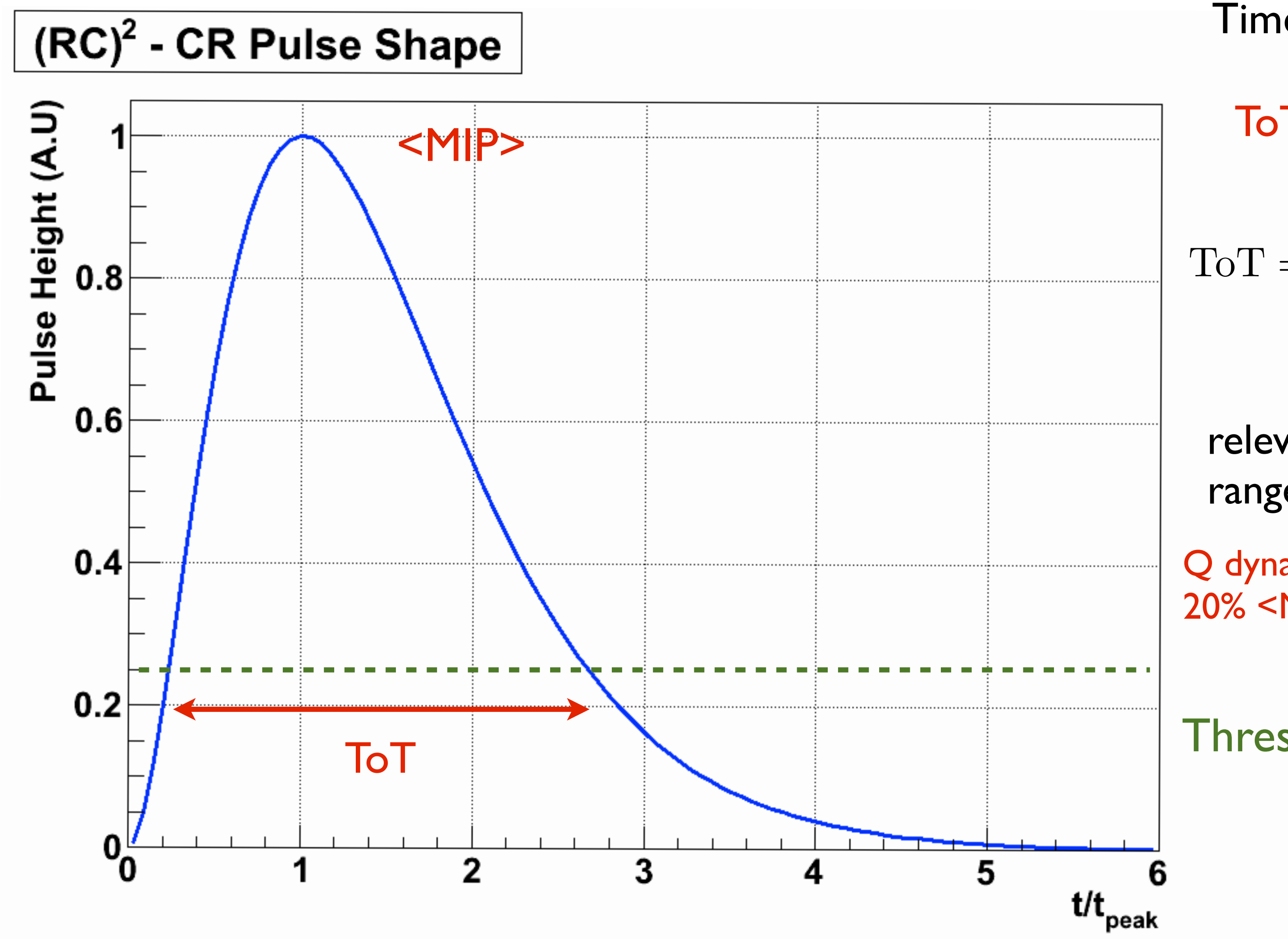
(from BaBar experience)

- BaBar note #126, B. A. Schumm, "dE/dx particle identification with a five layer silicon tracker".
- BaBar note #161, N. Roe, "Silicon strip resolution for Time-over-threshold readout".
- BaBar note #213, R. Becker et. al., "Silicon Vertex detector readout chip - Requirement specifications".
- BaBar note #214, R. Becker et. al., "Silicon Vertex detector readout chip - Target design specifications".
- BaBar note#501, A. Perazzo and N. Roe, "User's guide to the Atom IC".
- Gerry Lynch's notes:
    - http://www.slac.stanford.edu/~grl/dedxtalkDec98.html
    - http://www.slac.stanford.edu/~grl/PHTables.html
- Giuliana Rizzo's talk:
    - http://agenda.infn.it/getFile.py/access?contribId=6&resId=0&materialId=slides&confId=3583

Pulse height information for SVT hits

- Relevant information for:
  - dE/dx measurements for low momentum tracks with low number of DCH hits (e.g. bkg rejection of electron positron pairs at SuperB);
  - improving hit spatial resolution w.r.t. digital information (pitch/$\sqrt{12}$);
  - correcting time walk and improve time resolution of hits. Implications on background reduction for hit reconstruction.

Pulse Shape for ideal $(RC)^2$-CR shaper



Time over Threshold (ToT)

ToT ∝ ln(PH/Thr) ≈ ln(Q)

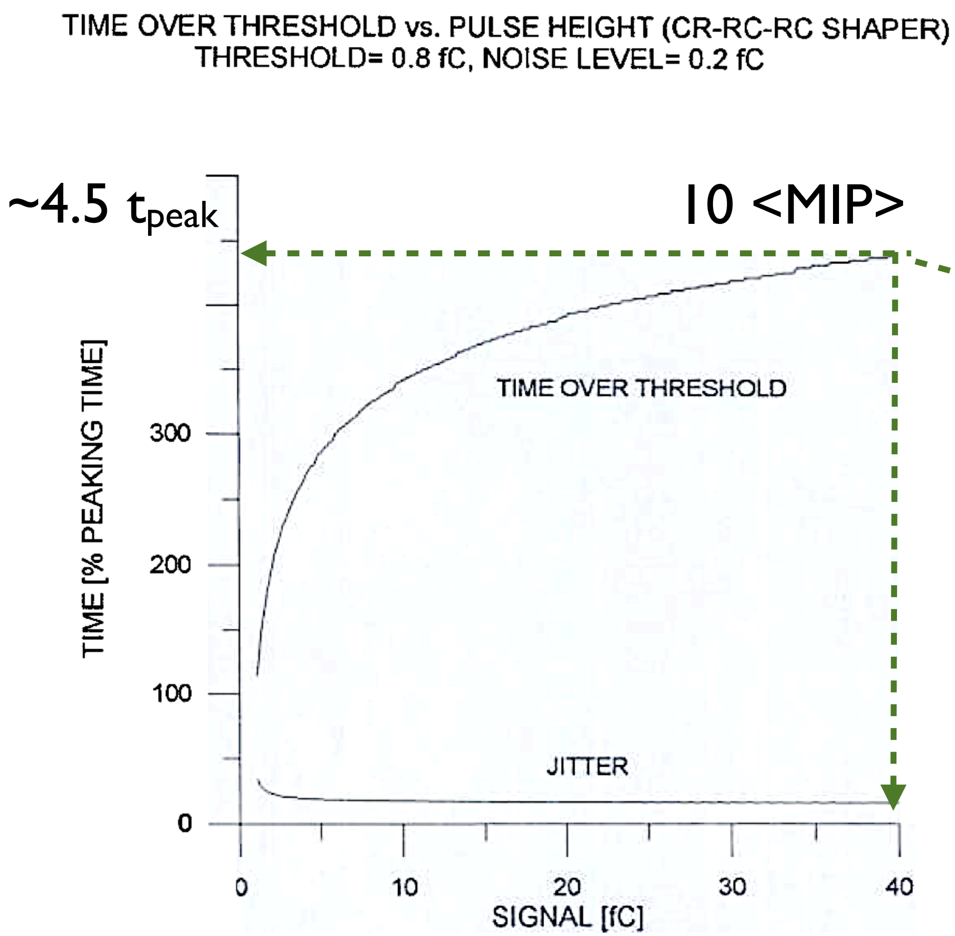
$$\mathrm{ToT} = Int\left(\frac{t}{t_{peak}}\frac{t_{peak}}{t_{clk}} + 1.5\right)$$

relevant parameter for Q range and resolution.

Q dynamic range of interest: 20% <MIP> up to 15 <MIP>

Threshold: 1/4 <MIP>

ToT from ideal $(RC)^2$-CR shaper



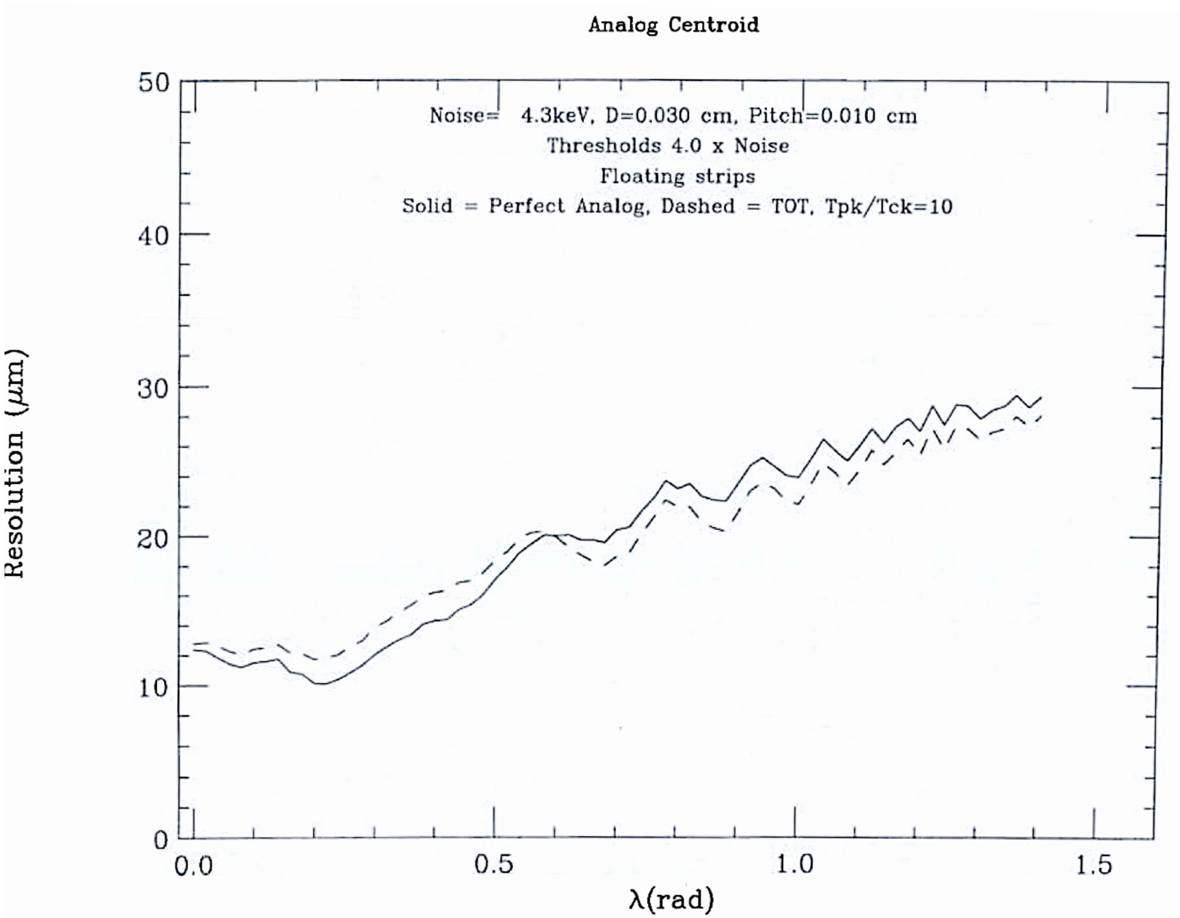
$$\text{ToT} = Int\left(\frac{t}{t_{peak}}\frac{t_{peak}}{t_{clk}} + 1.5\right)$$

$$\text{ToT} = Int\,(4.5 \times 3 + 1.5) = 15$$

4 bits for ToT is OK for a Ph dynamic range ≳10 <MIP> with max(t_{peak}/t_{clk})=3

Hit resolution with ToT: BaBar solution

From BaBar note#161, N. Roe



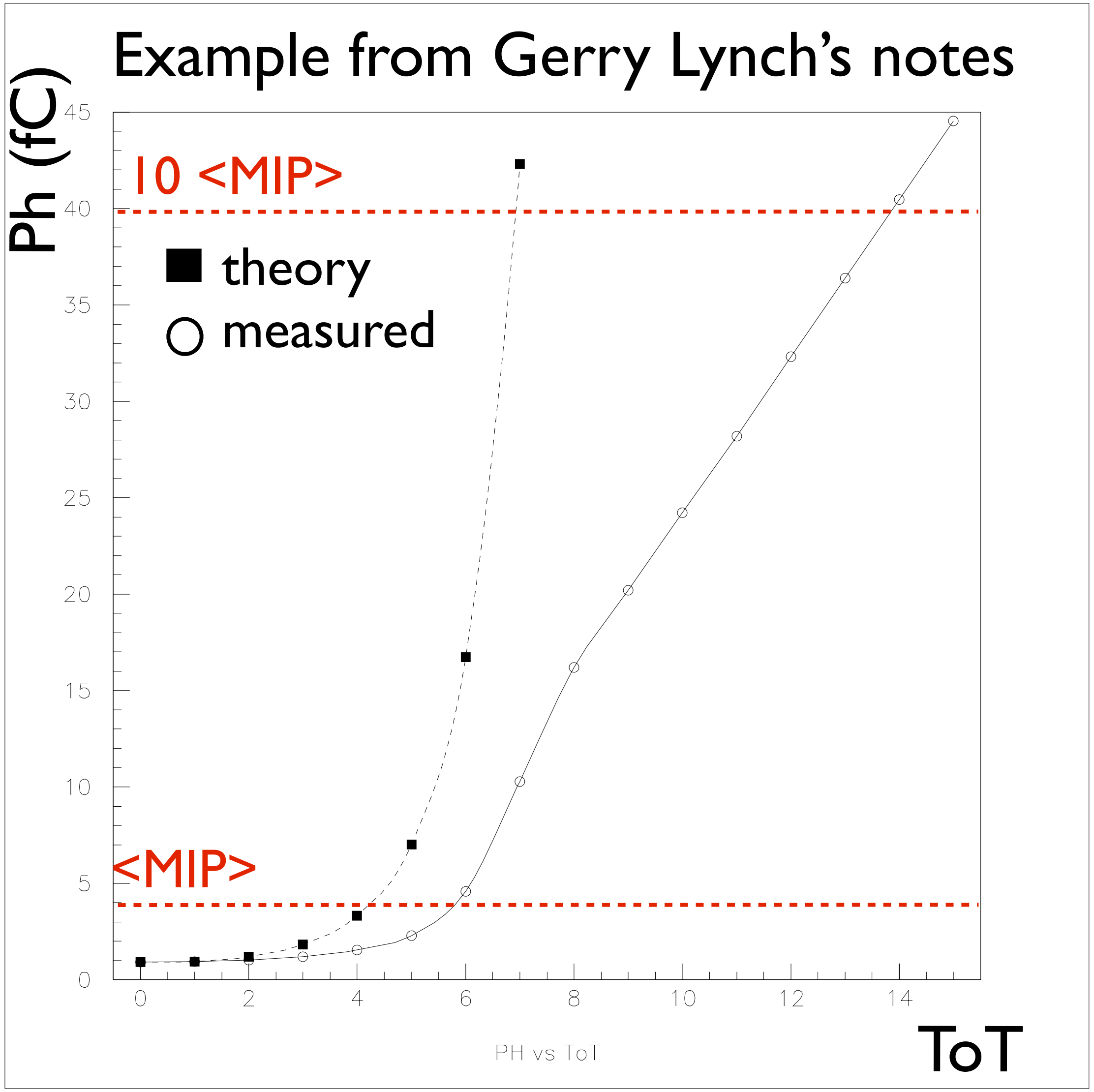
✓ 4 bit ToT with $\frac{t_{peak}}{t_{clk}} \simeq 10$ allows hit resolution compatible with perfect analog information;

✓ BaBar used $\frac{t_{peak}}{t_{clk}} \simeq 3$; even with $\frac{t_{peak}}{t_{clk}} \simeq 1$ very good hit resolution. Only 20% reduction of performance;

t_{peak}= 200 (400) ns for inner (outer) layers

t_{clk} = 67 ns (default) but can be adjusted at chip configuration level with skip control: 67xn (n=1,2,3,4) ns.

From ToT to Pulse Height and dE/dx



- ToT to Ph conversion: differences from theory behavior can be corrected with "Ad hoc" calibrations.
- ToT is converted into Ph (i.e. dE/dx) using lookup tables.
- for tracks with signals in at least 4 layers, a 60% truncated mean dE/dx is calculated. Cluster with smallest dE/dx is also removed (electronic noise).
- Dynamic range of about 10-15 <MIP> with 4 bit of ToT: obtained a resolution for MIPs of about 14%.

Example of ToT response in AToM-1 chip

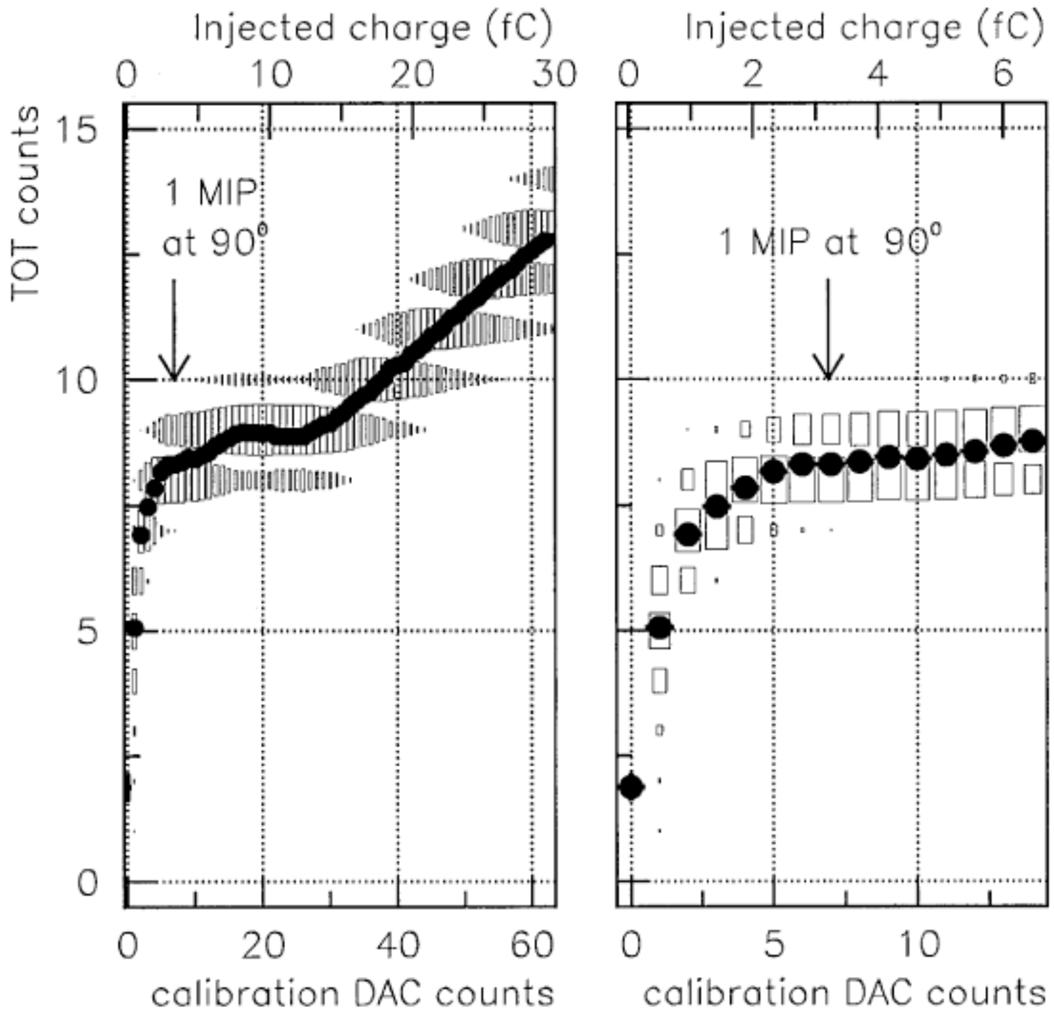
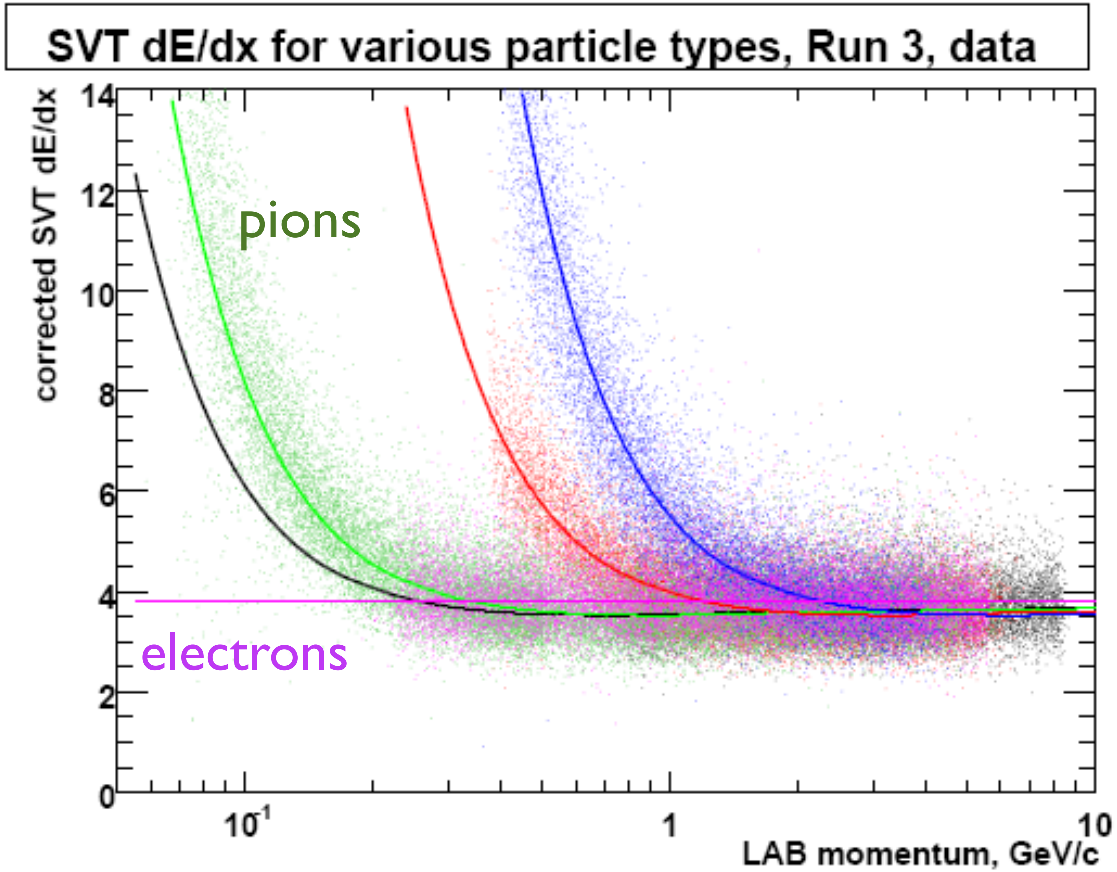
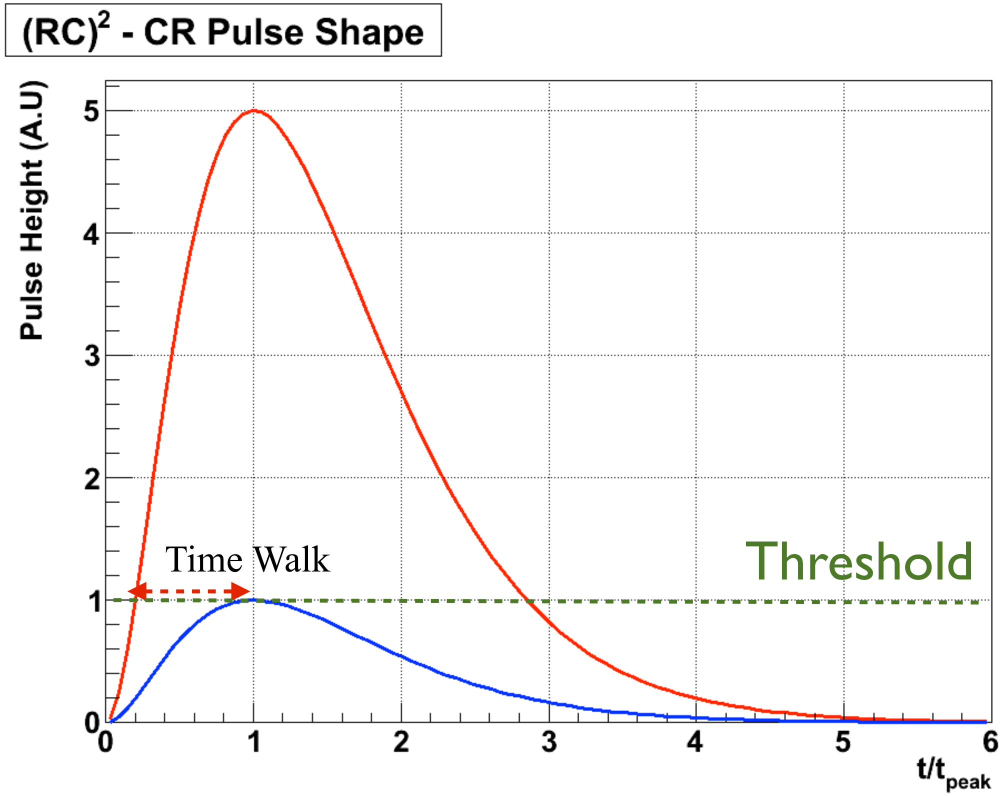


Fig. 2. Measured Time-Over-Threshold response for one AToM-I chip as a function of injected charge for a peaking time of 200 ns and a sample rate of 15 MHz. One TOT count corresponds to 67 ns. One calibration DAC count corresponds to about 0.5 fC of injected charge. The area of each box is proportional to the number of hits. Each dot is the average TOT value for that calibration DAC setting. The plot on the left shows the full calibration DAC range. The plot on the right shows up to a calibration DAC setting of 15.

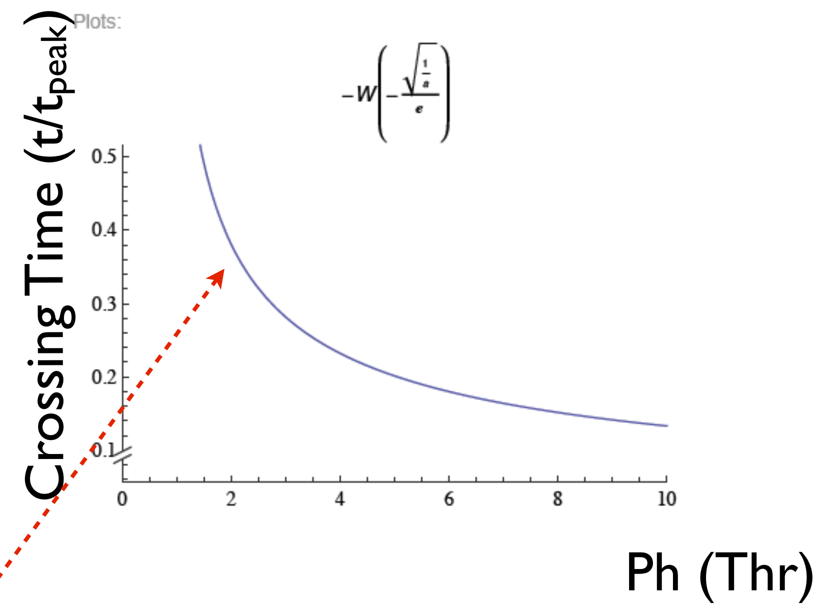
SVT dE/dx in BaBar with ToT



Time Walk Correction



Threshold crossing time vs Ph



- Time walk can be corrected offline if Ph information is known. Important to have good time resolution for SVT hits for bkg hit suppression.
- Time walk scales with t_{peak} and correction precision depends on Ph resolution. Important to have good resolution at low Ph.

Summary

- dE/dx with SVT measurements is crucial at SuperB for reducing bkg from low p_T electron-positron pairs. This was not the case at BaBar.
- In BaBar, dE/dx measurement with SVT with 4 bit ToT and 10-15 <MIP> Pulse height (Ph) dynamic range allows for 14% resolution for MIPs. There might be room for improvement here. Alternatives to ToT? Flash ADC information?
- With ToT, Ph dynamic range depends on t_{peak}/t_{clk} (~3 in BaBar), on number of ToT bits and finally on ToT response of the chip. A Ph dynamic range of 10-15 <MIP> is required.
- ToT provides excellent information for cluster centroid determination. Compatible with perfect analog information. Difficult to do better in this case.