Analysis Note on the Validation of the ORCA Simulation of the Endcap Muon CSC Front-end Electronics

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Introduction

- In preparation for the Physics TDR, Part 1, we want to document work done mainly by N. Terentiev on validating the ORCA simulation of the endcap muon CSC front-end electronics.

- We have submitted an Analysis Note 2005/066 describing the work, and we hope to get approval so that it can become a full CMS Note that can be referenced in the TDR.

- I will give a summary of the method and the results described in the note.

Cathode Front-end Electronics

- Pulses on each cathode strip are amplified, shaped and then sampled every 50 ns by a switched capacitor array (SCA). When a trigger is received, 8 consecutive SCA samples are digitized and readout. See figure on next slide.

- ORCA must correctly simulate the pulse shape and the cross-talk on the neighboring strips.

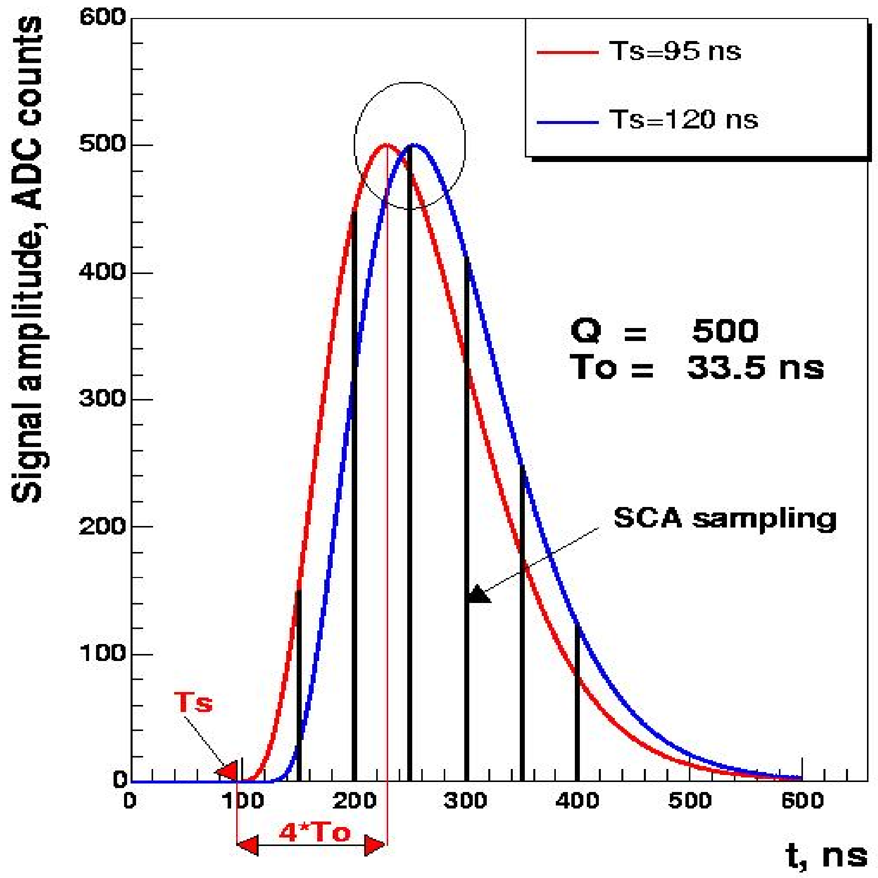
- Parameter values in ORCA were taken from preproduction electronics and early test-beam results. How good is the simulation?

Example of 2 Pulse Shapes

Pulse-shape parameters:

T_s = Pulse arrival time.

T_0 = ¼ of Pulse peaking time.



Data Used

- Use test-beam data from 2003/2004 with final electronics – 150 GeV/c muon beam, 4 different types of CSCs, and a 25 ns LHC-like beam structure.

- Also have special pulser data taken in April at SX5 to measure the pulse shape of the cross-talk signal.

- Fit the pulse height shape on the middle strip and the two neighboring strips for the 4 SCA time samples near the pulse peak. Compare results for test-beam data, pulser data and from the ORCA simulation.

- Use 100 GeV/c single-muon ORCA events in full CMS geometry. OSCAR_3_7_0 and ORCA_8_7_1.

Example of SCA Test-beam Data to Fit

Time (ns) / Strip	25	75	125	175	225	275	325	375
Left Strip	0	0	41	110	88	41	18	5
Middle Strip	0	3	112	420	512	370	214	122
Right Strip	0	1	33	85	57	16	6	3

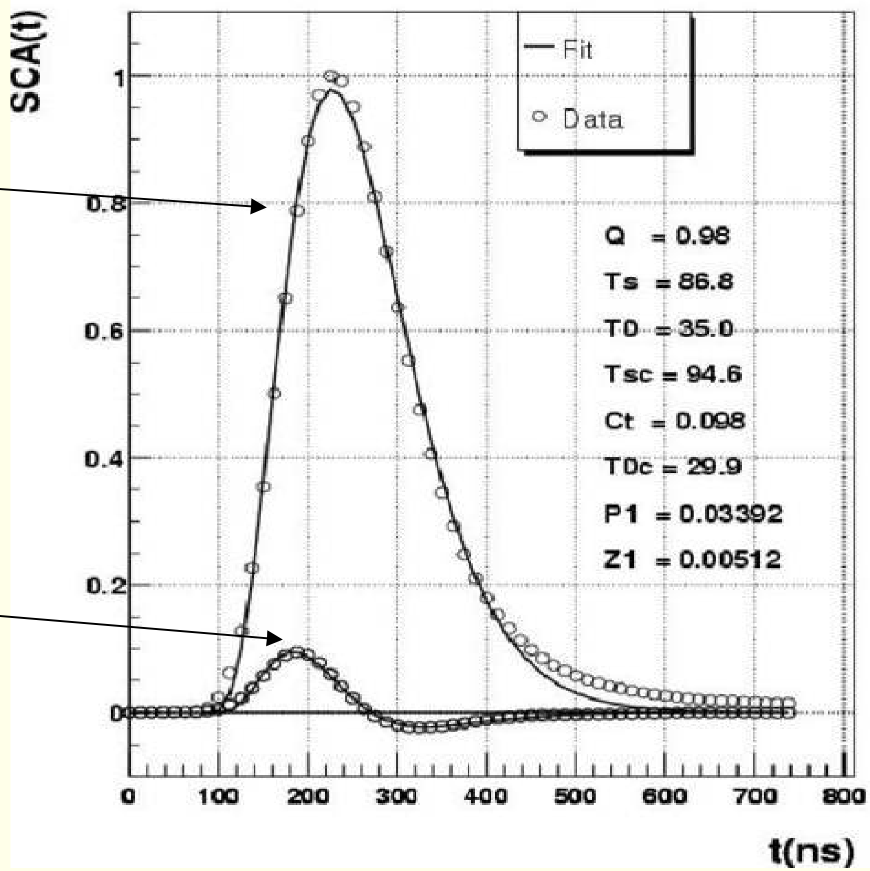
Fit to Data

- Important fit parameters are the peaking time, $4T_0$, (T_0 = 35 ns) of the signal pulse and the cross-talk coefficient, C_t (C_t = 0.1) between the neighboring strips.
- We first fit the pulser data to get the pulse shape for the cross-talk pulses on the neighboring strips. (See next slide.)
- Then fit the test-beam and pulser data and the ORCA simulation data to find the peaking time and cross-talk.
- Compare the resulting distributions of the peaking time and the cross-talk coefficient.

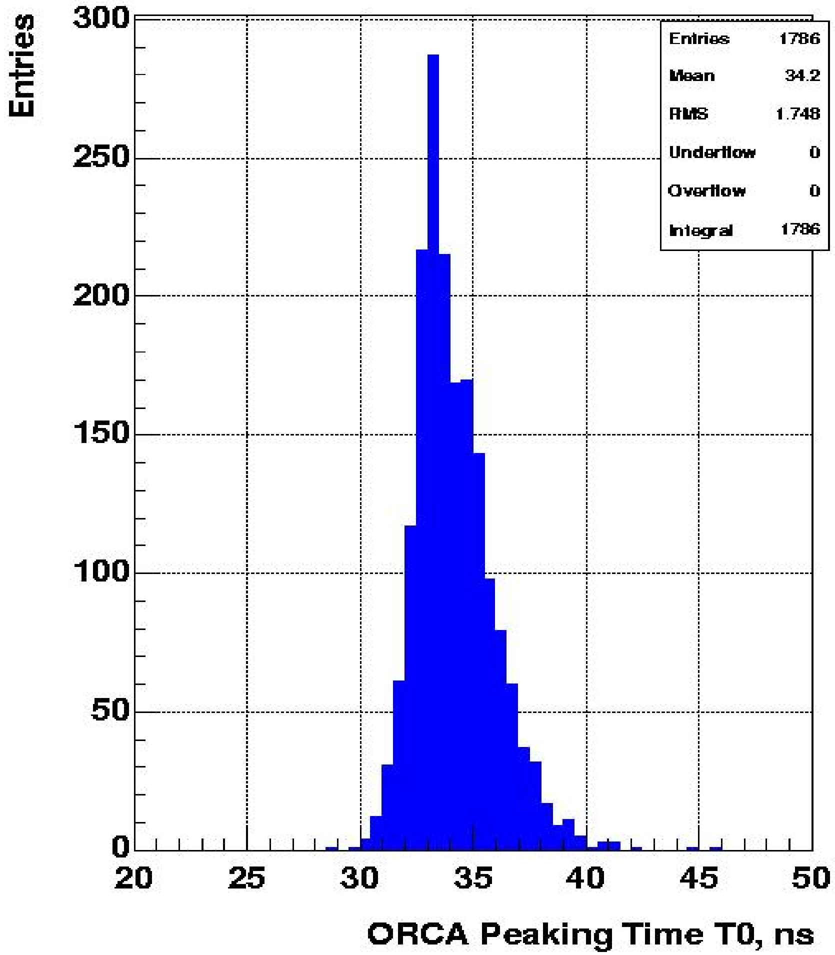
Pulse Shapes from fit to Pulser Data

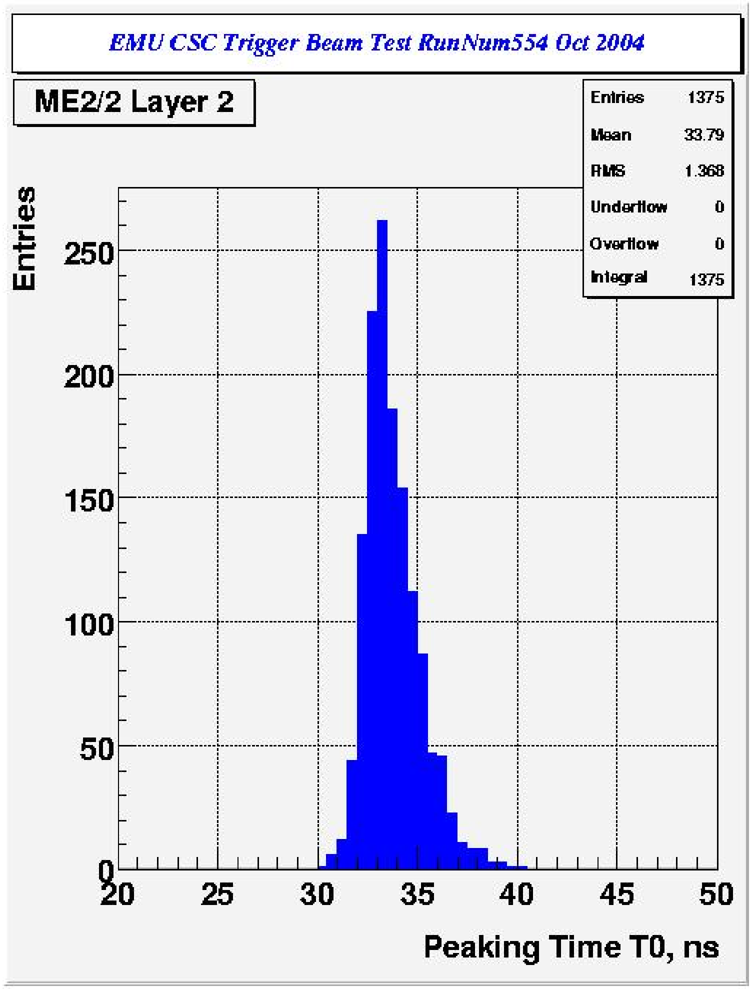
Pulsed middle strip

2 side strips with cross-talk

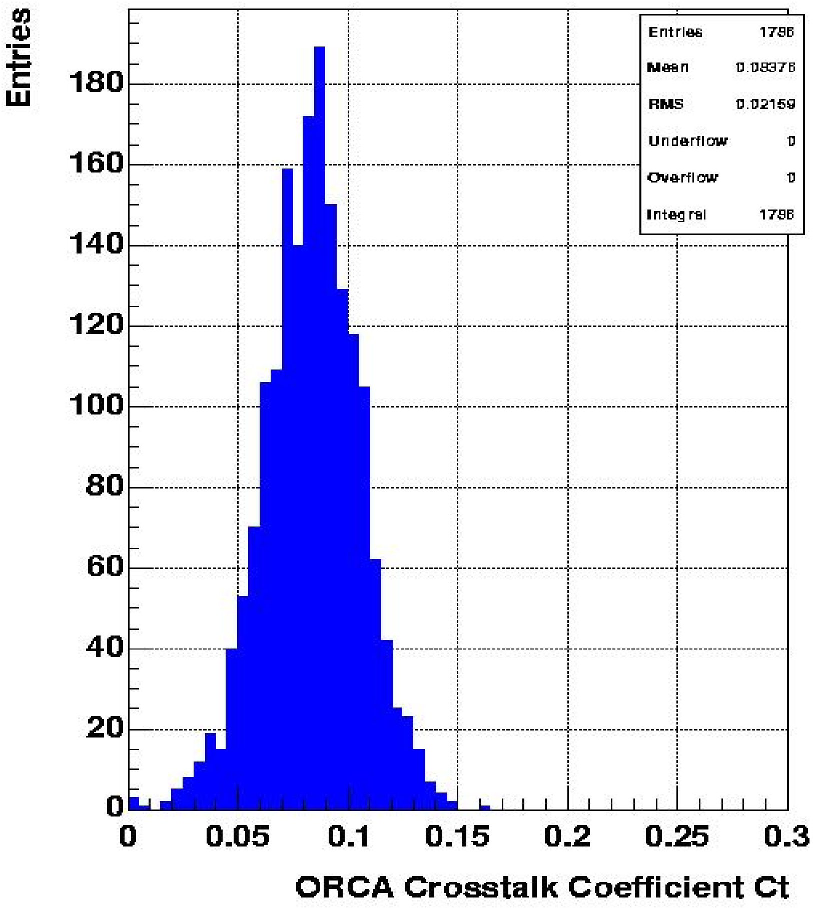


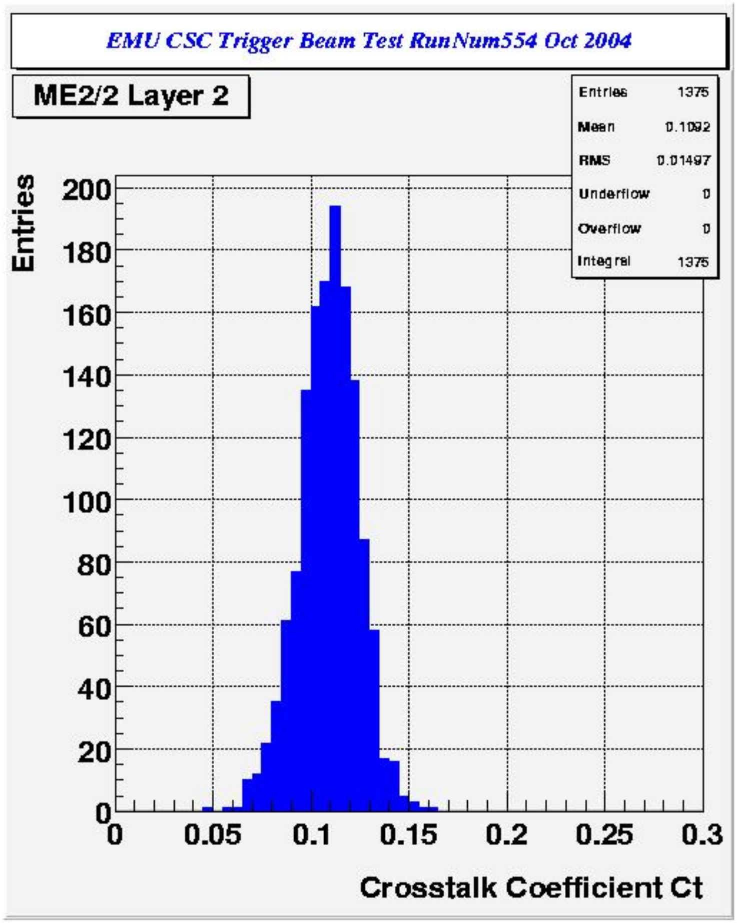
Comparison of Pulse Peaking Times in ORCA and in Test-beam Data





Comparison of Cross-talk Coefficients from ORCA and from the Test-beam





Numerical Results for Peaking Time and Cross-talk Coefficient

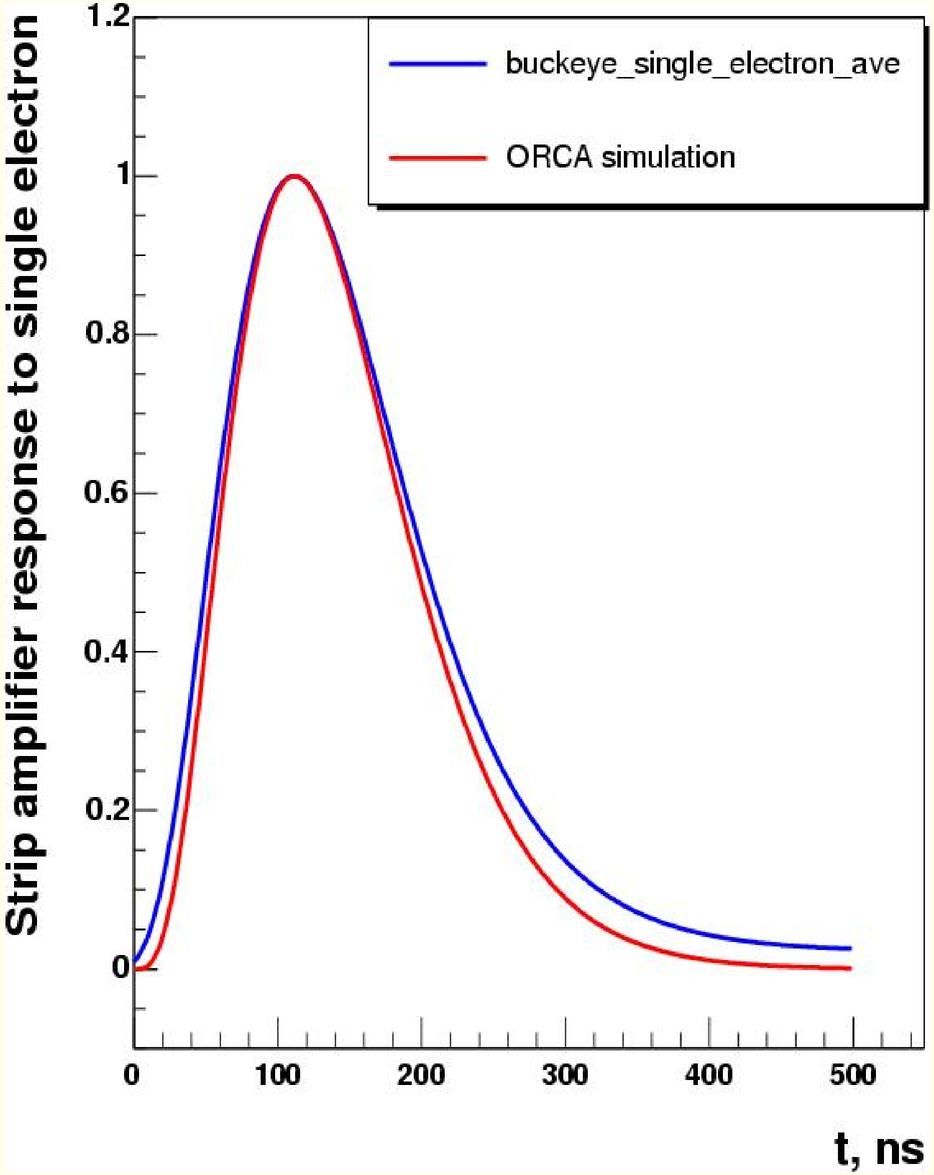
Data Type	Average T_0 (ns)	R.M.S. T_0 (ns)	Average C_t	R.M.S. C_t
Test-beam Data	34.2	1.3	0.099	0.014
ORCA Simulation	34.2	1.7	0.084	0.022
Pulser Data	34 - 36	--	0.095 – 0.098	--

Summary of Fit Results

- There is good agreement in the pulse peaking time between the ORCA simulation and the test-beam data. This was expected since the single-electron response function used in ORCA is quite close to the function determined for the production cathode front-end electronics. (See figure on next slide.)

- The cross-talk coefficients from ORCA are slightly lower than in the test-beam data. This was also expected, since the ORCA simulation treats the cross-talk using an old, approximate formula.

Comparison of ORCA and More Recent Single-Electron Response Functions



Pulse-shape Restoration

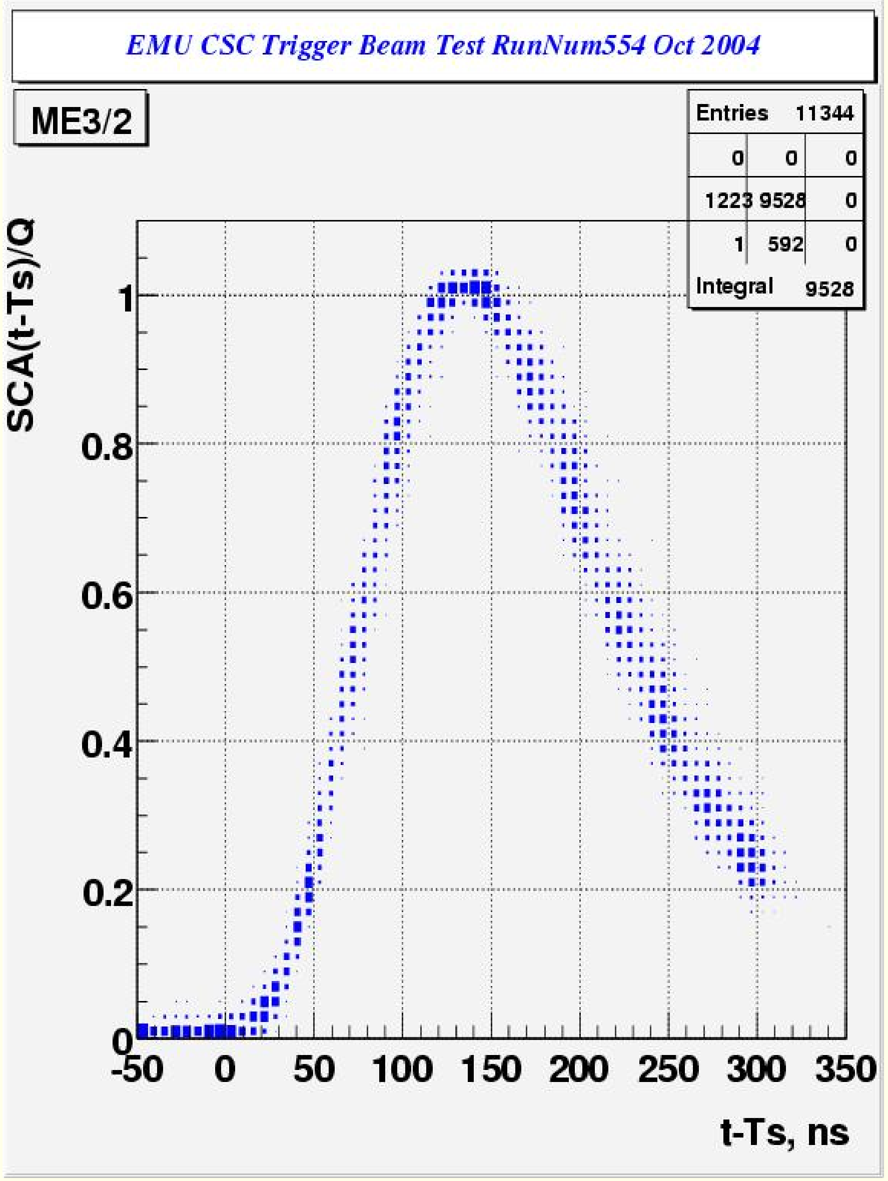
- Because of variations in trigger timing, electronics delays and electron drift times, the cathode pulses have a range of possible arrival times, T_s. This means that the SCA samples pulses at different times with respect to the beginning of the pulse.

- We can use this to reconstruct the pulse shape with a much finer resolution than the 50 ns SCA sampling time. We measure the pulse arrival time in the fit. Subtracting this value from each SCA sampling time for each event, gives us the “restored” cathode pulse shape. We can do this for the test-beam and pulser data, as well as for the ORCA simulation. Results are on the next slides.

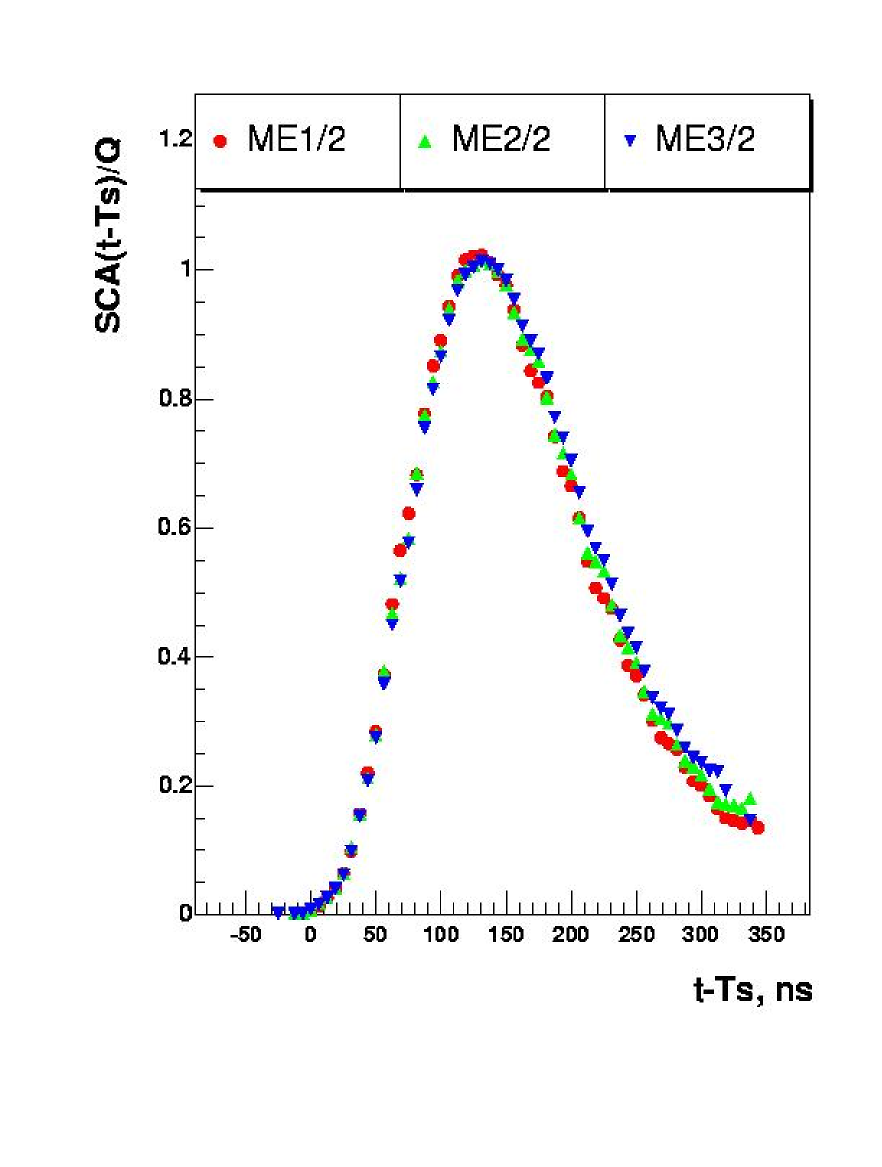
Restored Pulse Shapes from a Single Layer of CSC from Test-beam Data

Plot SCA($t-T_s$)/Q for each pulse vs. $t-T_s$, where SCA is the ADC value for each time bin and Q is the total charge on the strip.

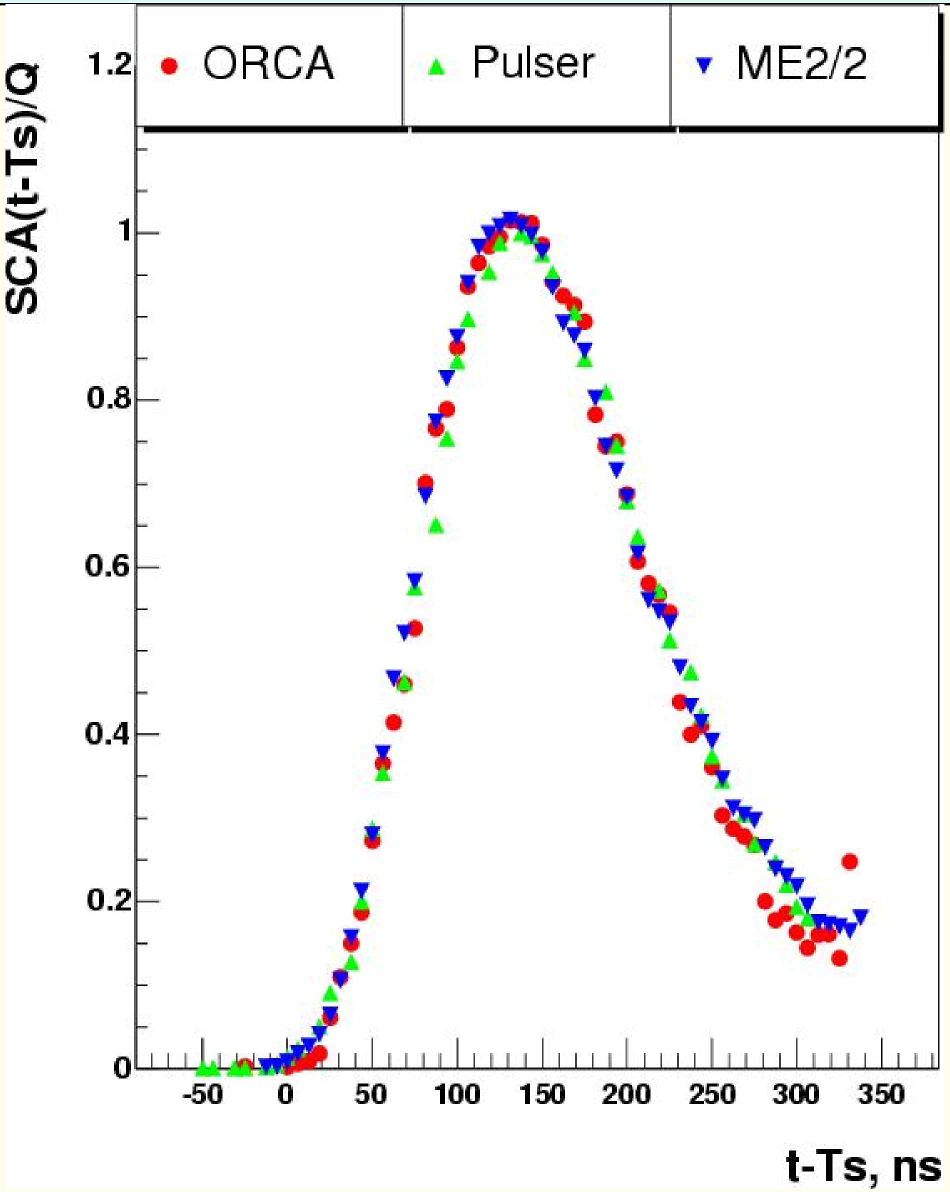
This should give a universal "restored" pulse shape.



Average Pulse Shapes for Different CSCs from Test-beam Data



Comparison of Pulse Shapes for Test-beam, Pulser and ORCA Simulation



Measurement of Cross-talk versus Time

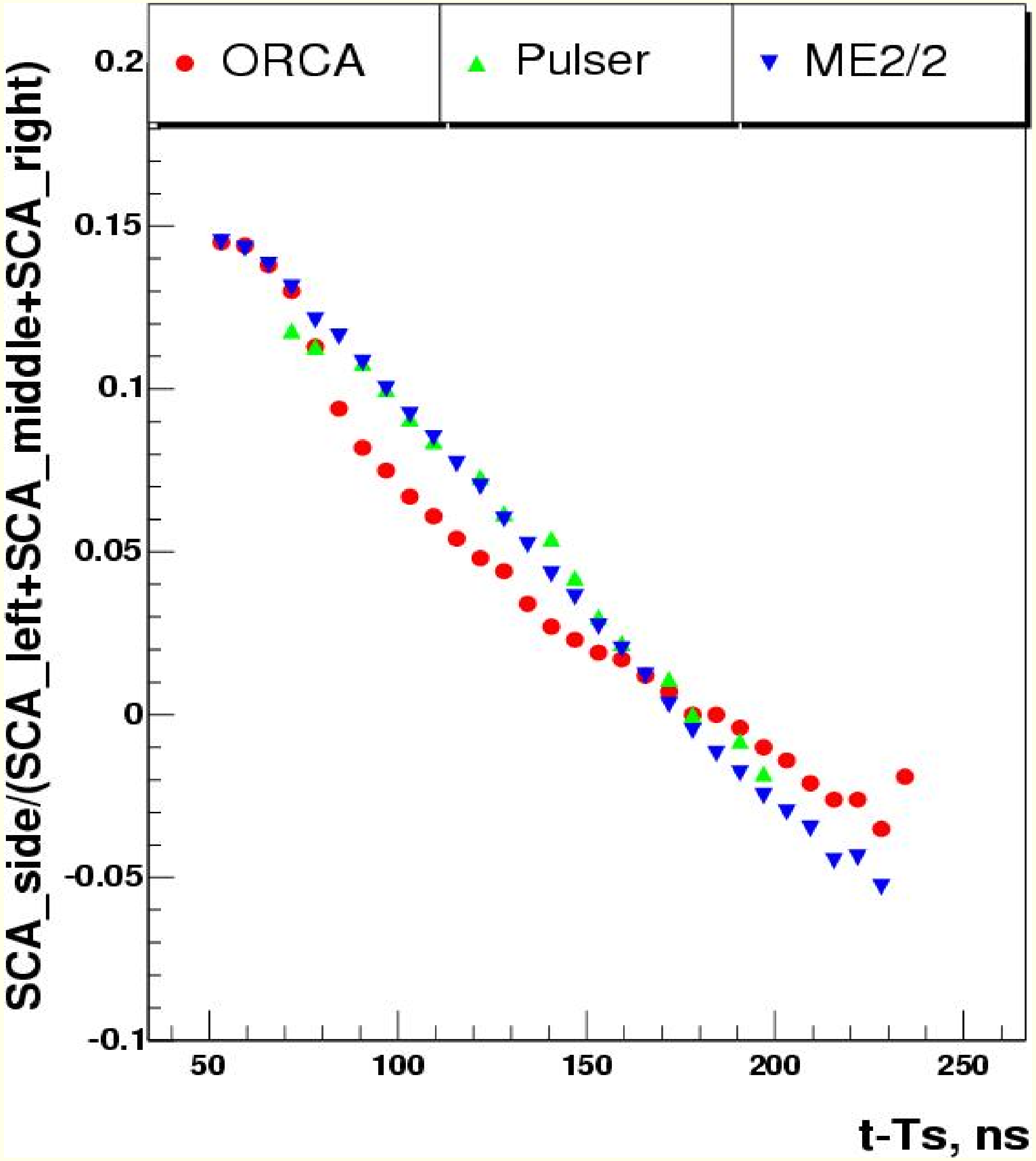
- Using the restored pulse shape with the arrival time subtracted, we can also measure the cross-talk on the neighboring strips as a function of time for the test-beam and pulser data, and in ORCA.

- Plot:

$$\frac{SCA_{left}(t)}{SCA_{right}(t) + SCA_{middle}(t) + SCA_{left}(t)}$$

Cross-talk Ratio versus Time for Test-beam, Pulser and ORCA Simulation

The cross-talk coefficient, C_t, is approximately the slope of these curves.
So these results are consistent with our earlier fitted results -> C_t is about 15% smaller in the ORCA simulation than in the test-beam and pulser data.



Summary

- The pulse shape of cathode strip signals simulated in ORCA agrees very well with the shape of real signals from test-beam and pulser data. This results comes from both fitting the pulses and from finding the “restored” pulse shapes.

- The cross-talk coefficients and the shape of the cross-talk pulses in ORCA are in reasonable agreement with the data, but more up-to-date values should be installed.