Electronic Calibration of the ATLAS Liquid Argon Calorimeters (LAr)

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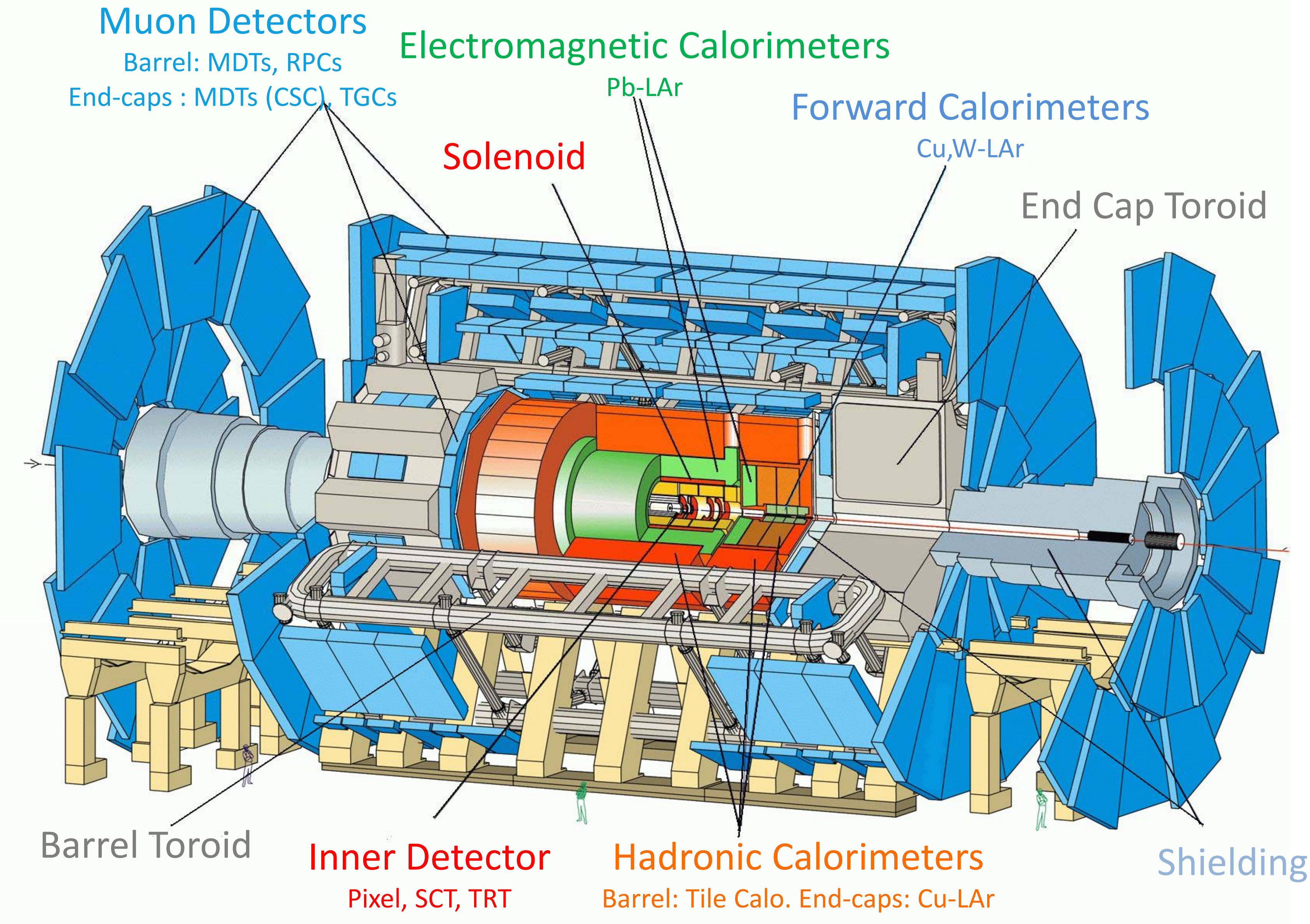
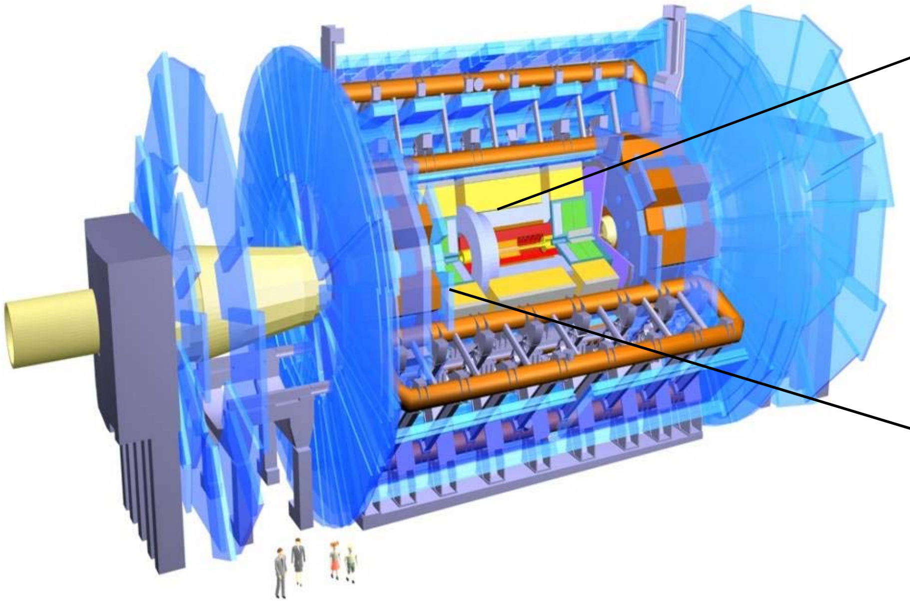
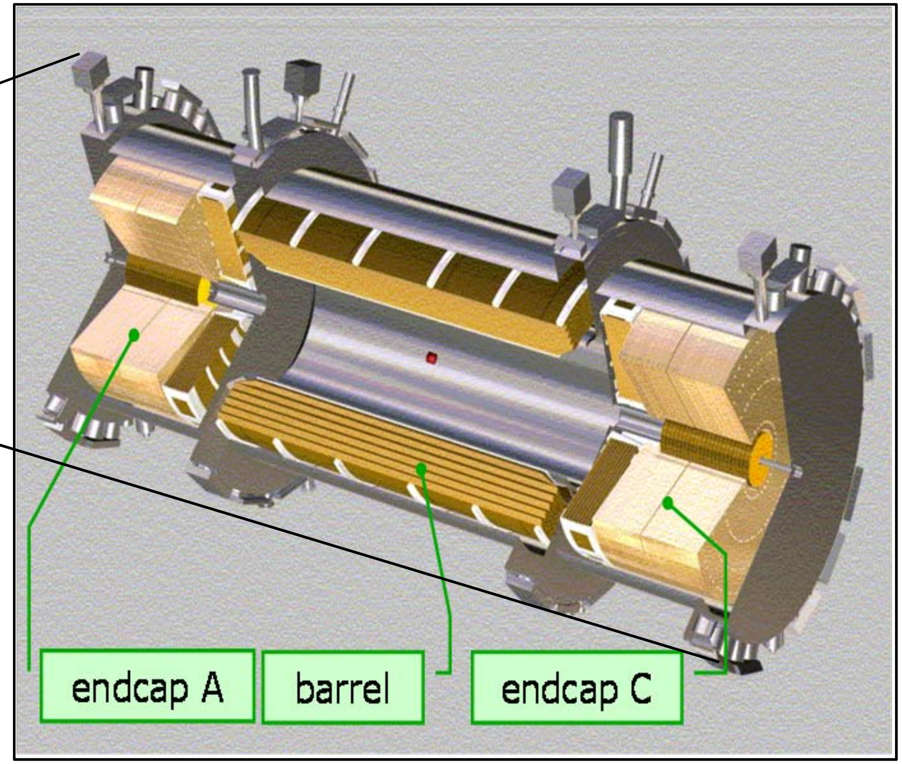
On behalf of ATLAS LAr group

ATLAS (A Toroidal LHC ApparatuS)



ATLAS LAr Calorimeters



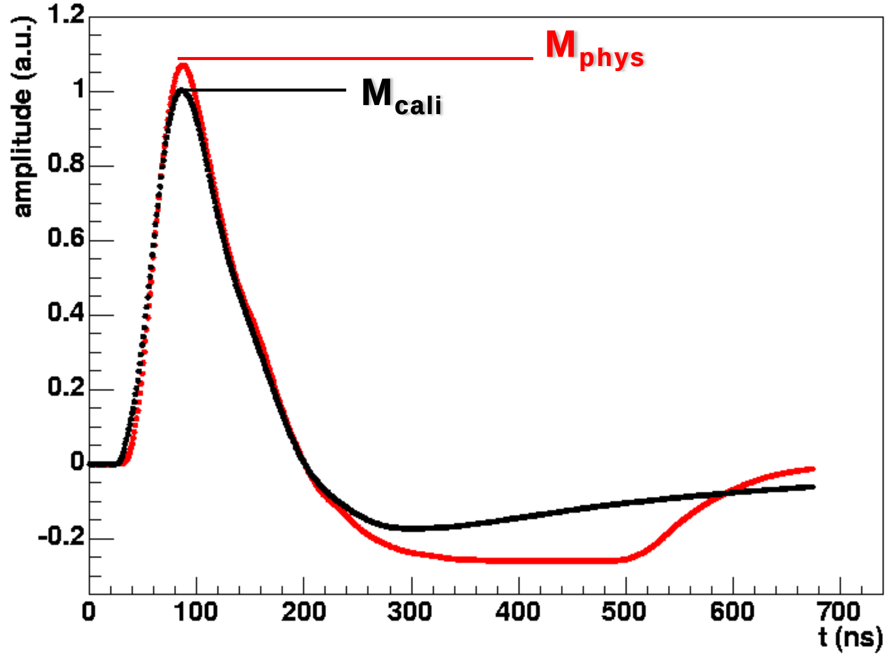


- LAr Calorimeters:
  - EM Barrel : $|\eta|<1.475$ [Pb-LAr] 101760 readout channels
  - EM End-caps : $1.4<|\eta|<3.2$ [Pb-LAr] 62208 channels
  - Hadronic End-cap: $1.5<|\eta|<3.2$ [Cu-LAr] 5632 channels
  - Forward Calorimeter: $3.2<|\eta|<4.9$ [Cu,W-LAr] 3524 channels
  - Presampler: 7808 barrel, 1536 endcaps
- ~190K readout channels

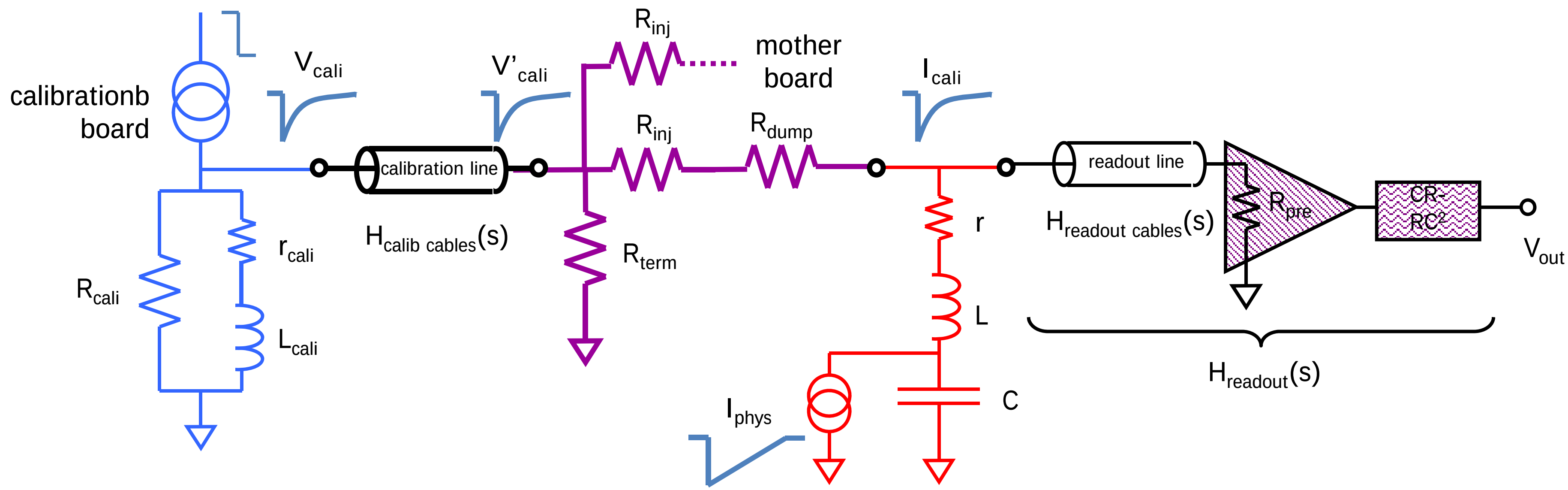
Energy reconstruction of a single cell

$$E_{\text{cell}} = F_{\mu\text{A}\to\text{MeV}} \cdot F_{DAC\to\mu\text{A}} \cdot \frac{1}{\frac{\text{M}_{\text{phys}}}{\text{M}_{\text{cali}}}} \sum_{i=1}^{M_{\text{ramps}}} R_i \left[\sum_{j=1}^{N_{\text{samples}}} a_j \left(s_j - p\right) \right]^j$$

- p: pedestals
- a_j: OF coefficients
- R_i: electronic gain (ramp), described by a M_{ramps} order polynomial
- $\frac{\text{M}_{\text{phys}}}{\text{M}_{\text{cali}}}$: factor accounting for the difference between the amplitudes of a calibration and an ionization signal of the same current
- $F_{DAC\to\mu\text{A}}$: DAC to current conversion factors (depends on R_{inj})
- $F_{\mu\text{A}\to\text{MeV}}$: current to energy conversion factor



LAr EM cell electrical model



- The ionization and calibration pulses differs...

$$I_{phys}(s) = I_{cali}(s) \times \frac{1}{H_{calib.\ cables}(s)} \times \left(\frac{(1 + s\tau_{cali})(sT_d - 1 + e^{-sT_d})}{sT_d(f_{step} + s\tau_{cali})} \right) \times \left(\frac{1}{1 + srC + s^2 LC} \right)$$

- Exponential pulse shape depends on CB elements

$$\begin{cases} f_{step} = \left(\frac{r_{cali}}{r_{cali} + \frac{R_{cali}}{2}} \right) \\ \tau_{cali} = \left(\frac{L_{cali}}{r_{cali} + \frac{R_{cali}}{2}} \right) \end{cases}$$

$$g^{\exp \rightarrow tri}(s) \qquad g^{MB \rightarrow \det}(s)$$

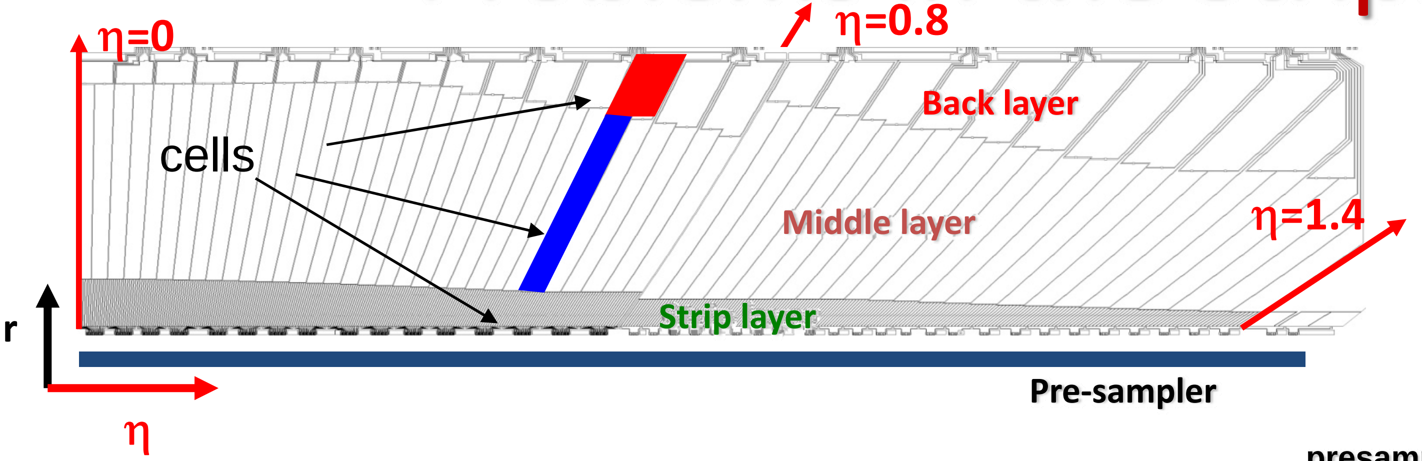
- As seen LC is an important parameter for physics pulse prediction needed for OFCs calculations.
- In Response Transformation Method (RTM), $\omega_o = 1/\sqrt{LC}$ is extracted by finding the minimum of the function

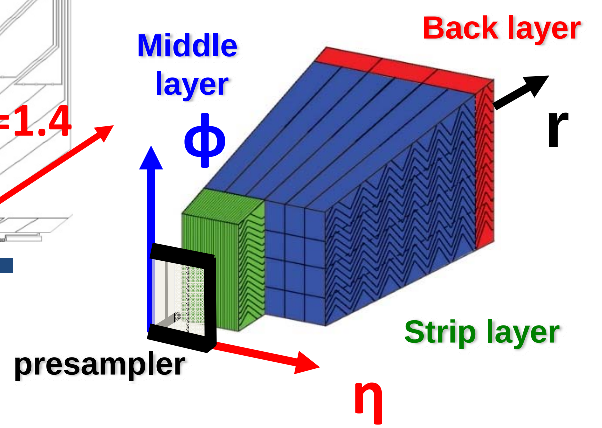
$$Q^2(\omega) = \sum_{t>t_{tail}} X_{out}^2(t;\omega)$$

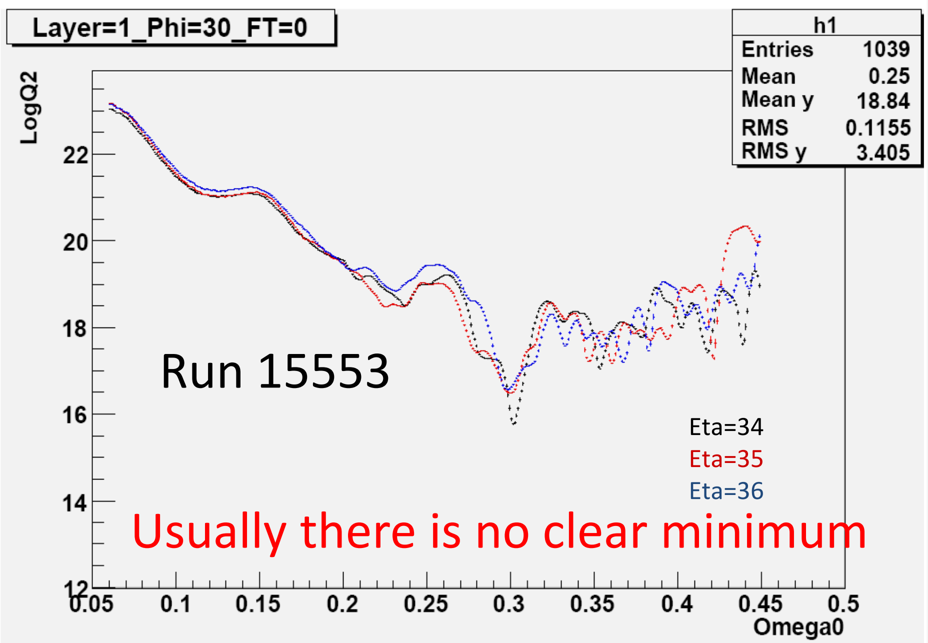
where $X_{out}(s;\omega) = C_{inj} \times H^{\det}(s) \times H^{readout}(s)$ is the response of the system to a cosine pulse of frequency ω.

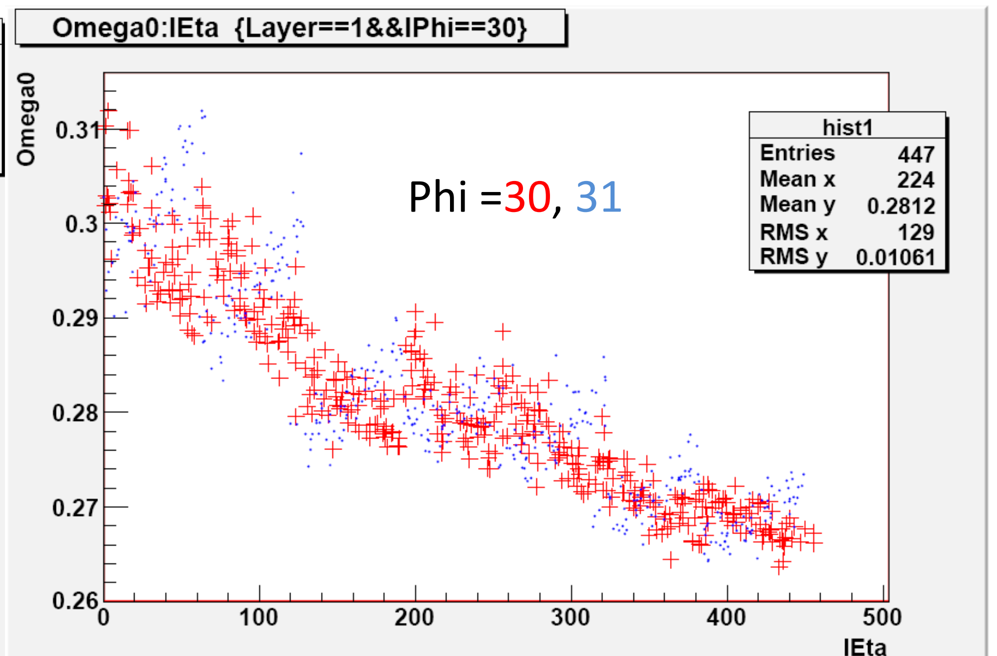
This method works fine for about 90% of the read-out channels.

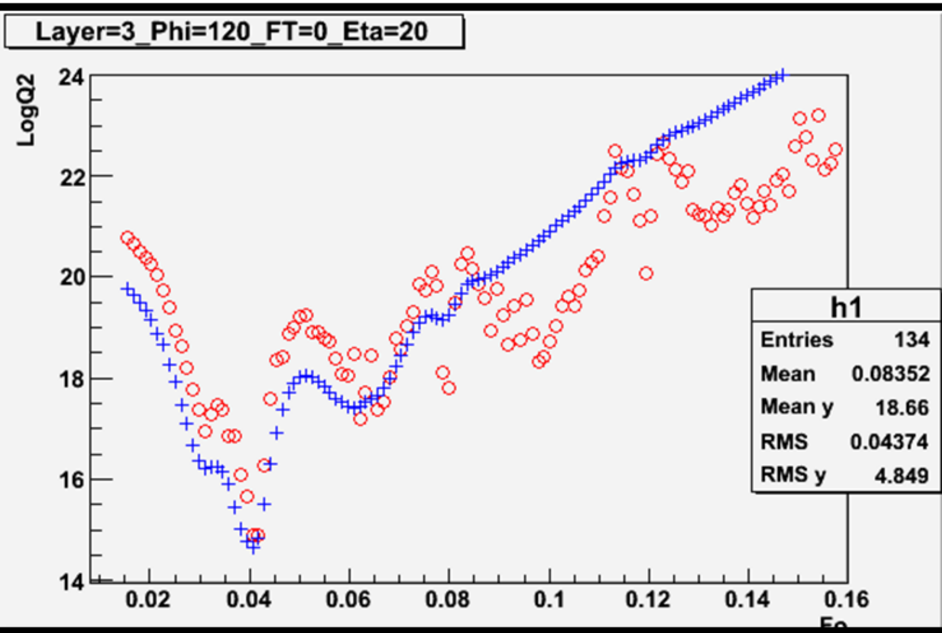
Problems in the Strips











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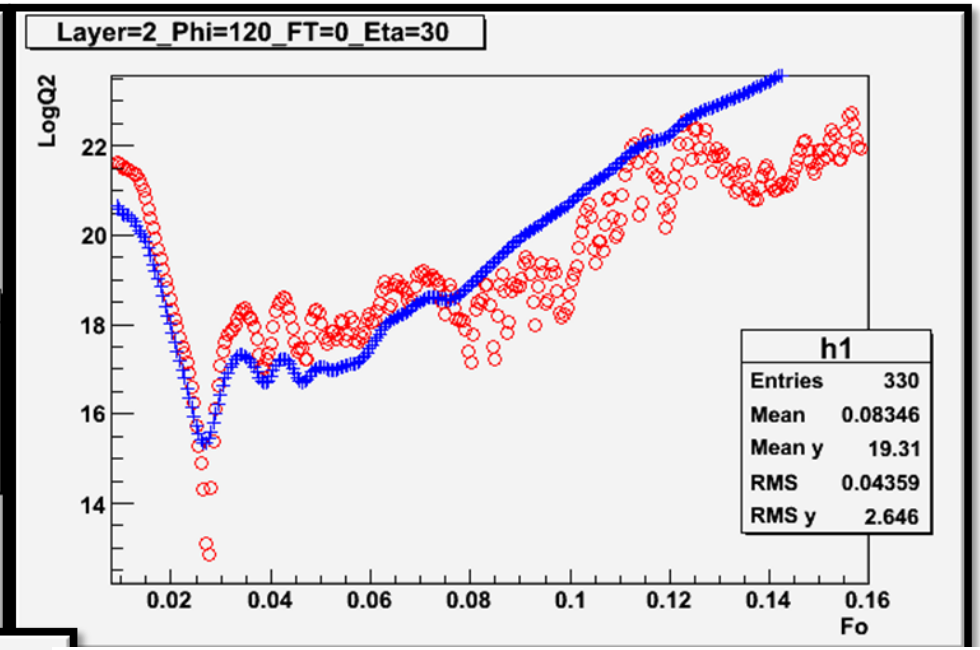
LogQ2
h1
Entries 134
Mean 0.08352
Mean y 18.66
RMS 0.04374
RMS y 4.849



Layer=2_Phi=120_FT=0_Eta=30
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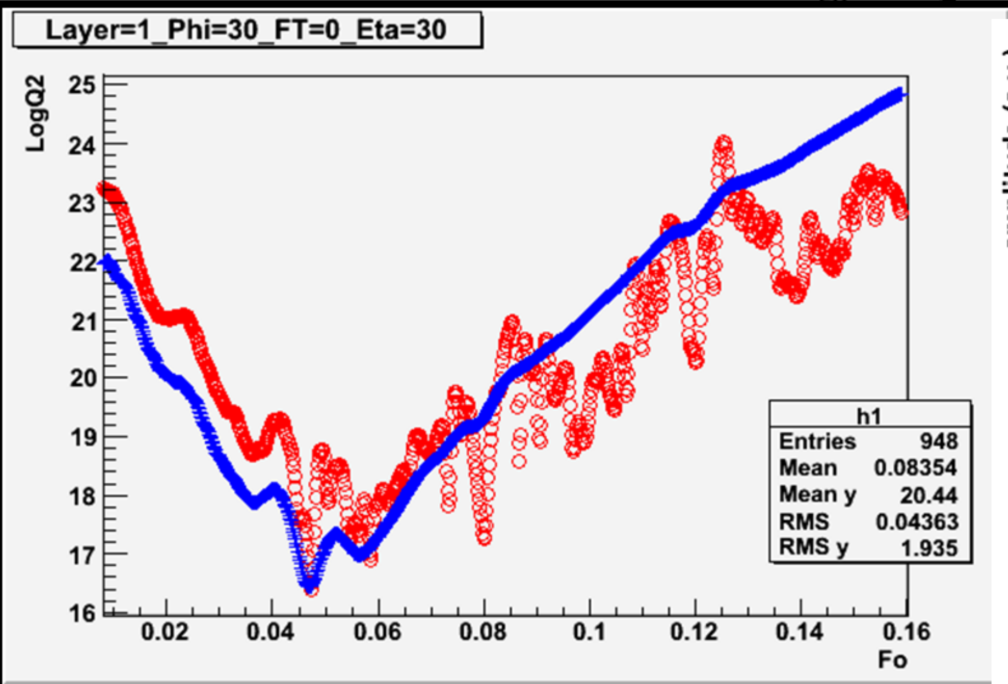
h1
Entries 330
Mean 0.08346
Mean y 19.31
RMS 0.04359
RMS y 2.646
Fo



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h1
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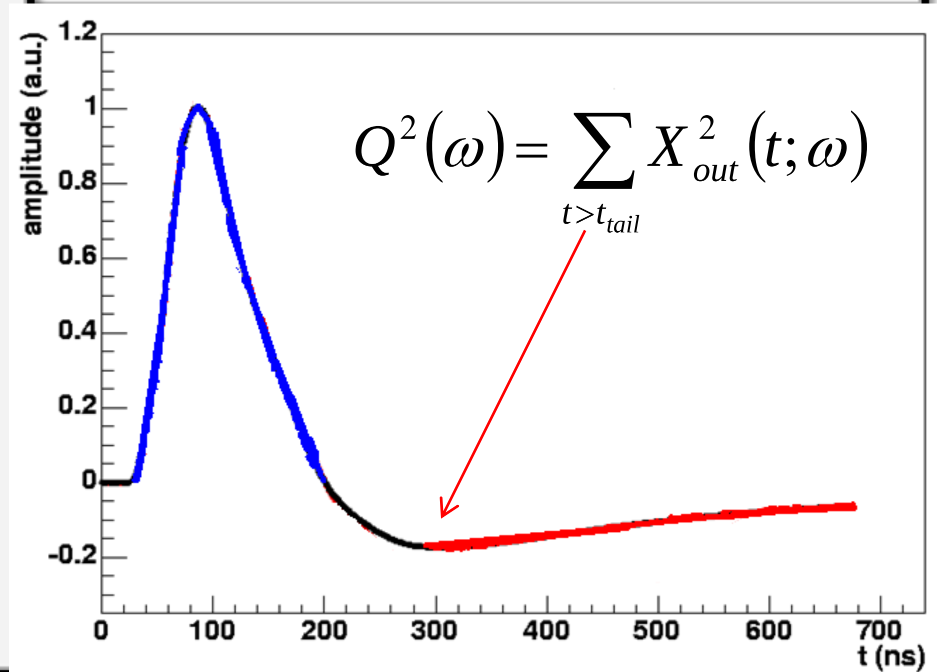
Mean y 20.44
RMS 0.04363
RMS y 1.935
Fo

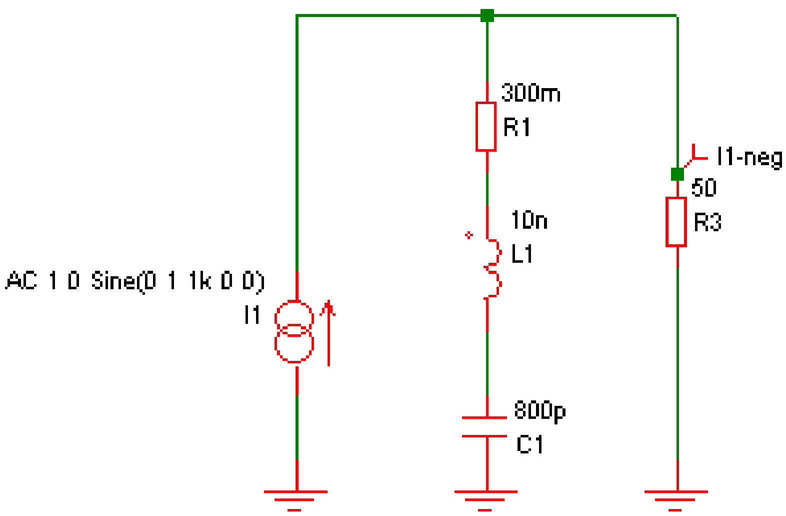


amplitude (a.u.)
$Q^2(\omega) = \sum_{t > t_{tail}} X_{out}^2(t;\omega)$
t (ns)

A circuit simulator as electrical detector model

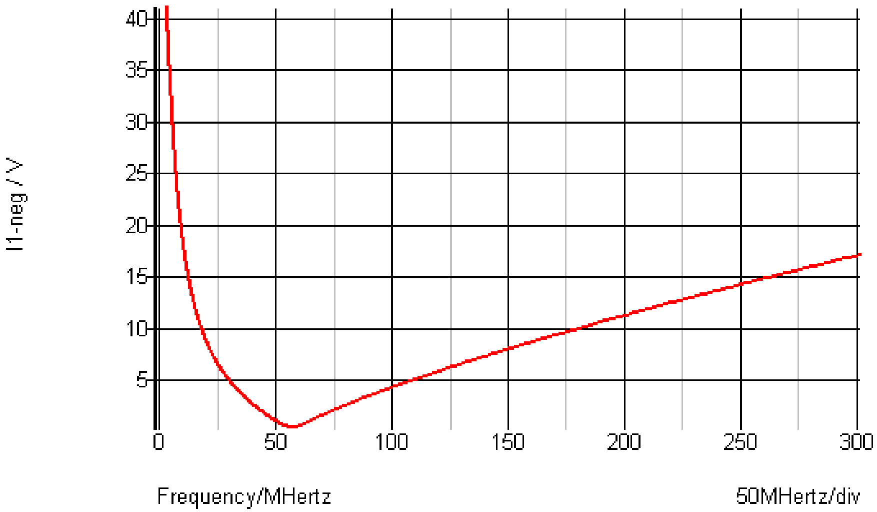
Using the SIMetrix
circuit simulation package

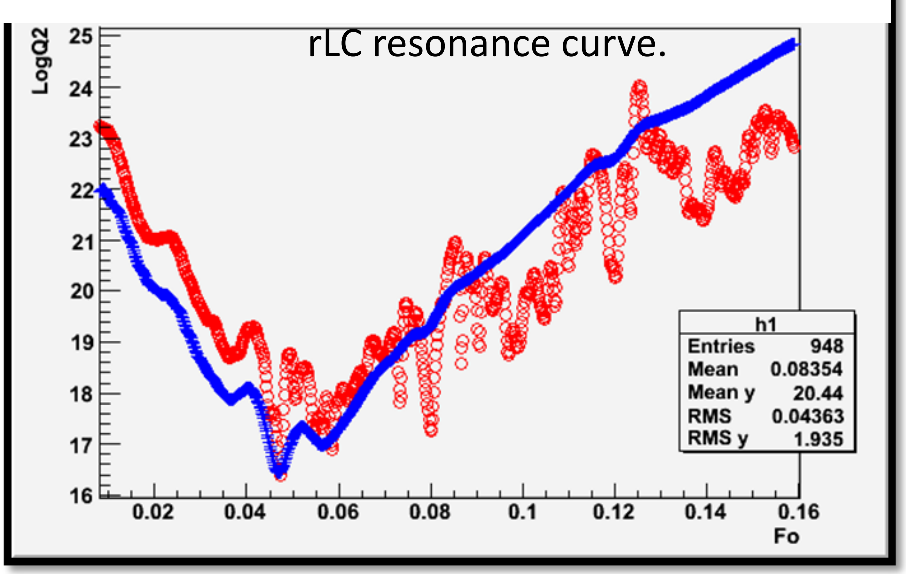
1- Single cell



Schematic of a cell

$$\upsilon_o = 1/2\pi\sqrt{LC} = 56.269MHz$$

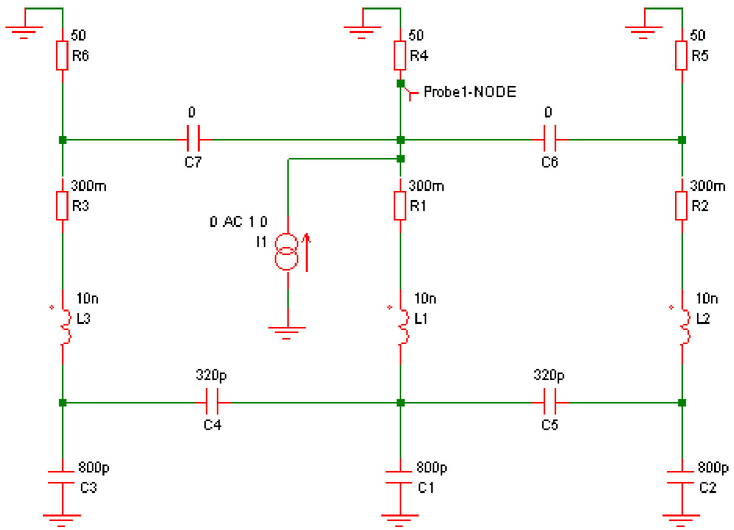




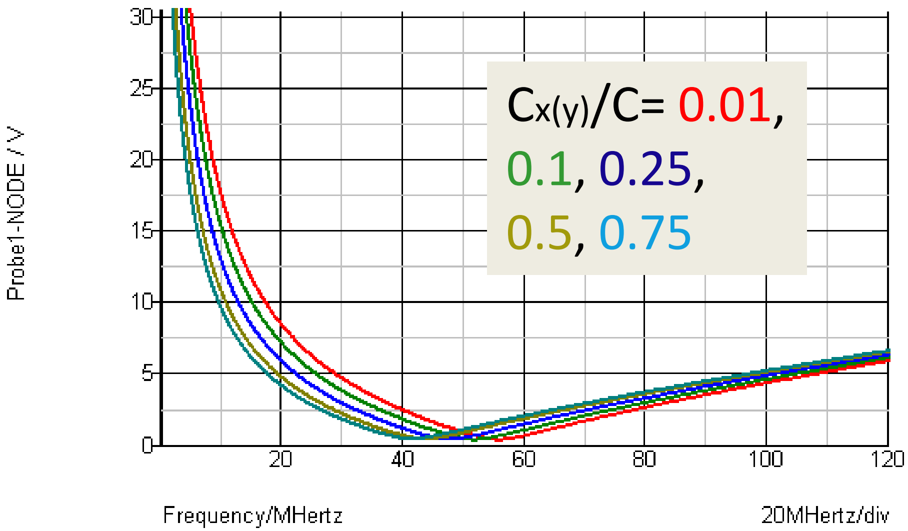
Adding neighbors

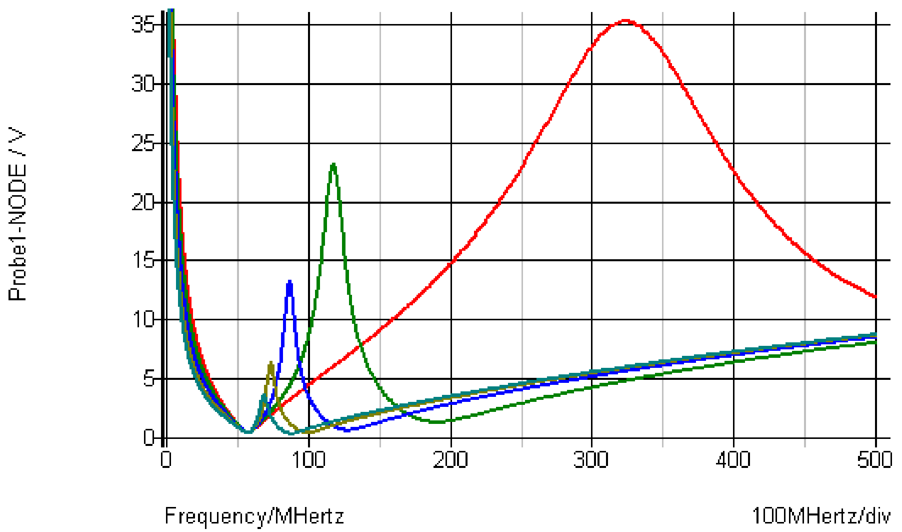
2- 1st neighbor

two X-talk
contributions Cx & Cy



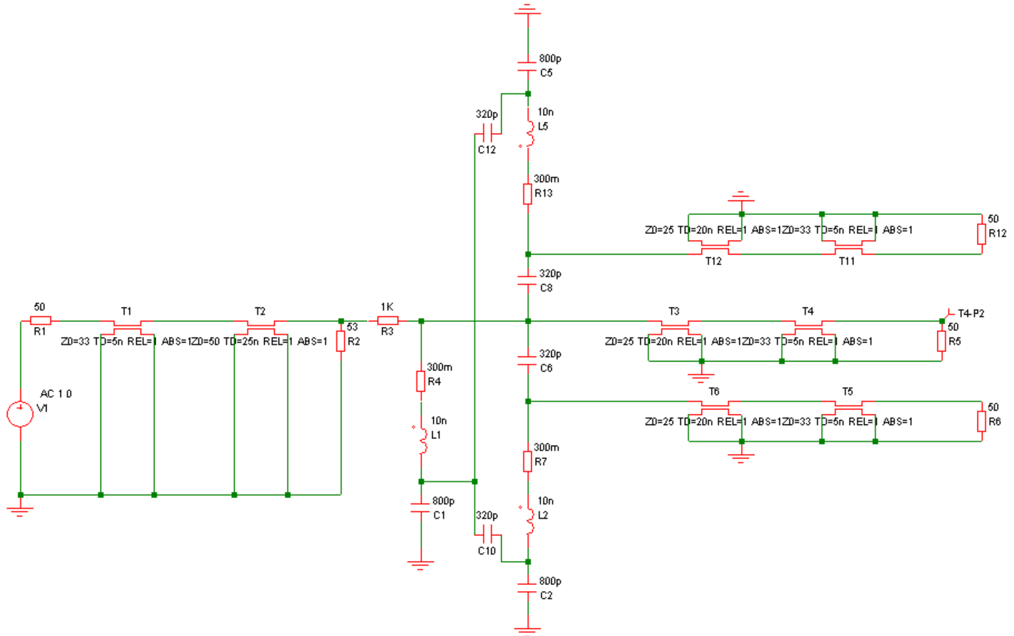
Schematic of a cell with a capacitive cross talk with just two neighboring cells one on each side.



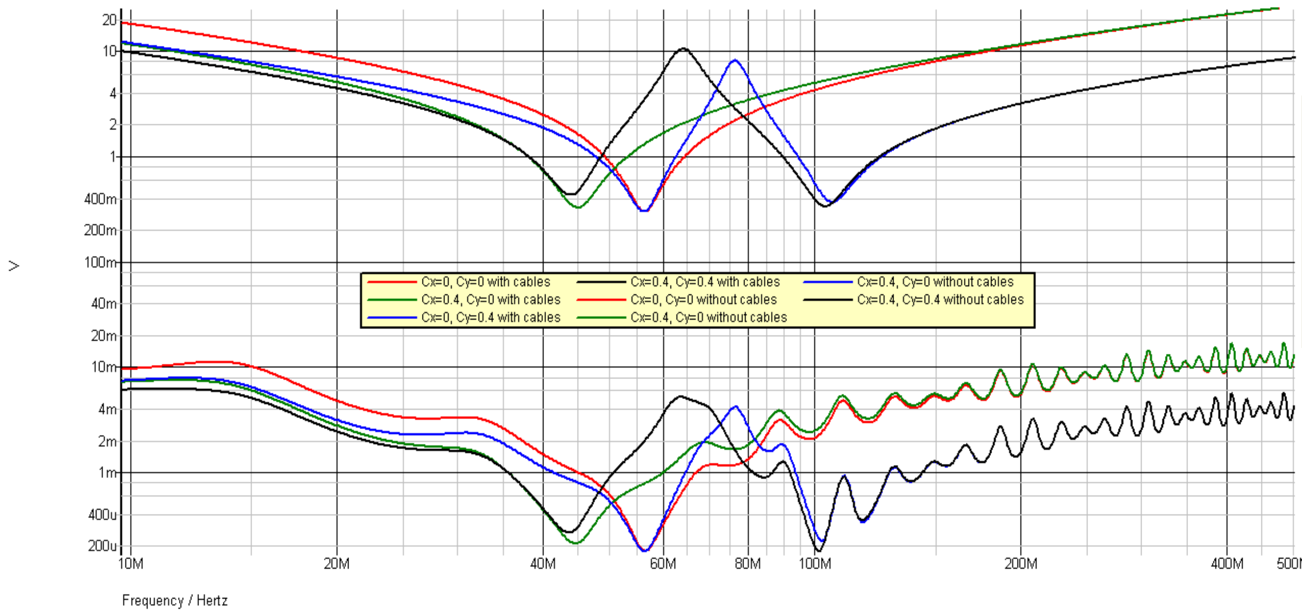


Resonance curves for different C_y values in case of only one neighboring cell

Adding cables



Schematic of a cell with a capacitive cross talk with 2 neighboring cells.



$C_x = C_y = 0$

$C_x = 0.4$ C and $C_y = 0$

$C_x = 0$ and $C_y = 0.4$ C

$C_x = 0.4$ C and $C_y = 0.4$ C

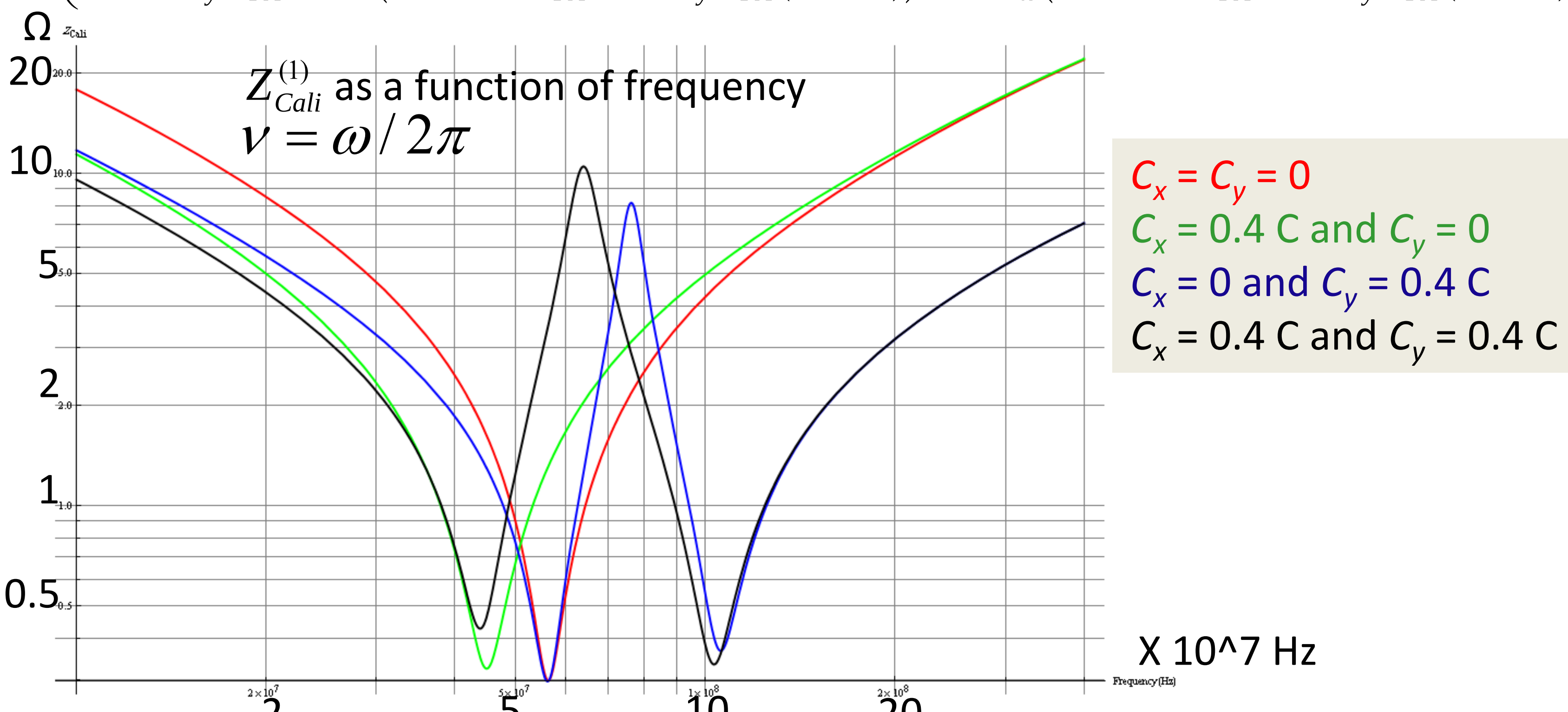
Analytical formulation of the capacitive X-talk effects

The total impedance of the calibration circuit as seen by the injected calibration current

1^{st} order neighboring cells (calib. current)

$$Z_{Cali}^{(1)} = \frac{V_{Out}^{(1)}}{i_{Cali}} = \frac{Z_{PA}}{3}\left(\frac{1+sC(r+sL)}{1+sC(r+sL+Z_{PA})}\right)$$

$$+\frac{Z_{PA}}{3}\left(\frac{2(1+s(C+3C_x)(r+sL))}{1+3sC_yZ_{PA}+sC(r+sL+Z_{PA}+3sC_yZ_{PA}(r+sL))+3sC_x(r+sL+Z_{PA}+3sC_yZ_{PA}(r+sL))}\right)$$



Doing the same calculations for the physics pulse, then take the ratio ;

$$R = \frac{V_{Out}^{\backslash(1)}}{V_{out}^{(1)}}$$

When considering that there is no cross-talk between the cells (C_x = C_y = 0), the above equation will be reduced to

$$R = \frac{i_{Phys}}{i_{Cali}} \times \frac{1}{\left(1 + srC + s^2 LC\right)}$$

$$g^{\exp \rightarrow tri}(s) \qquad g^{MB \rightarrow \det}(s)$$

R could be written as a series;

$$R = \frac{i_{Phys}}{i_{Cali}} \times \left[\frac{1}{1 + srC + s^2 LC} - \frac{2\varepsilon\left(srC + s^2 LC\right)}{\left(1 + srC + s^2 LC\right)^2} + \ldots\ldots \right]$$

Where $Cy=0$, $\varepsilon = Cx/C$

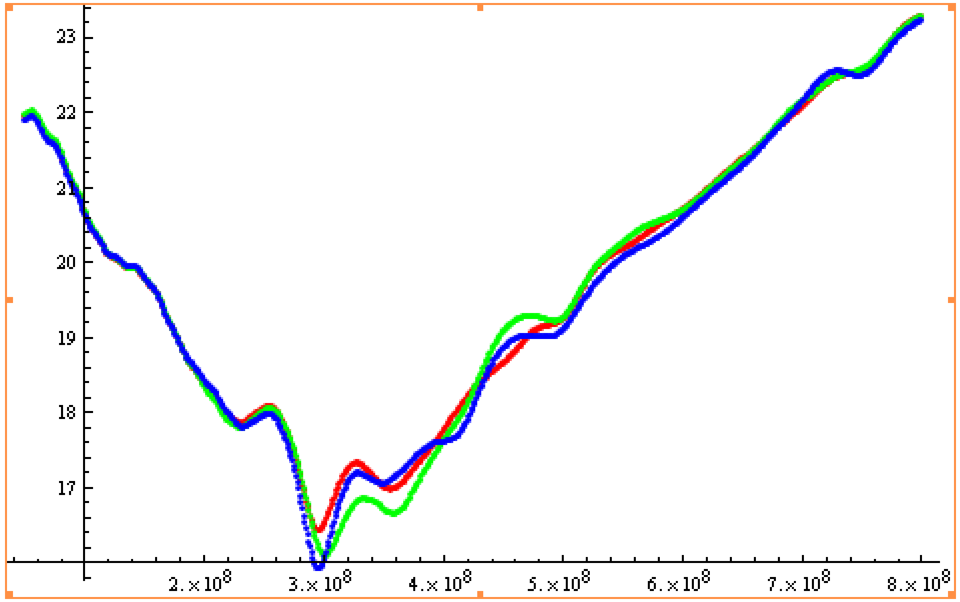
Conclusion

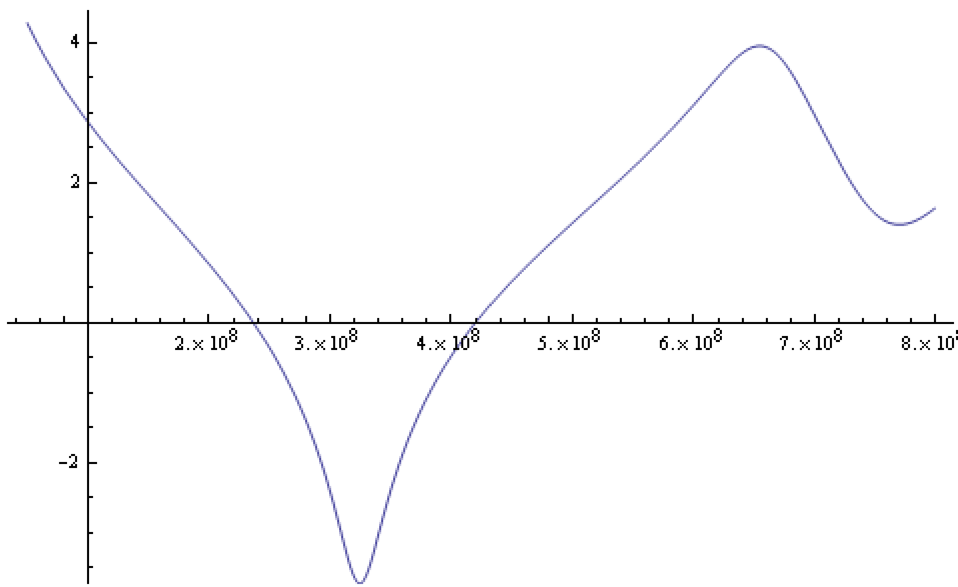
- $\omega_o = 1/\sqrt{LC}$ is expected to vary only weakly from cell to cell.
- Additional ω_o shifts are now understood to be from capacitive X-talk on the level of the LAr gap C_X . That gives uncertainty in the single cell energy.
- Small variations are coming from capacitive X-talk at the read-out level C_Y .
- No frequency shifts come from the variations in the path resistance and the preamplifier input impedance.

Outlook

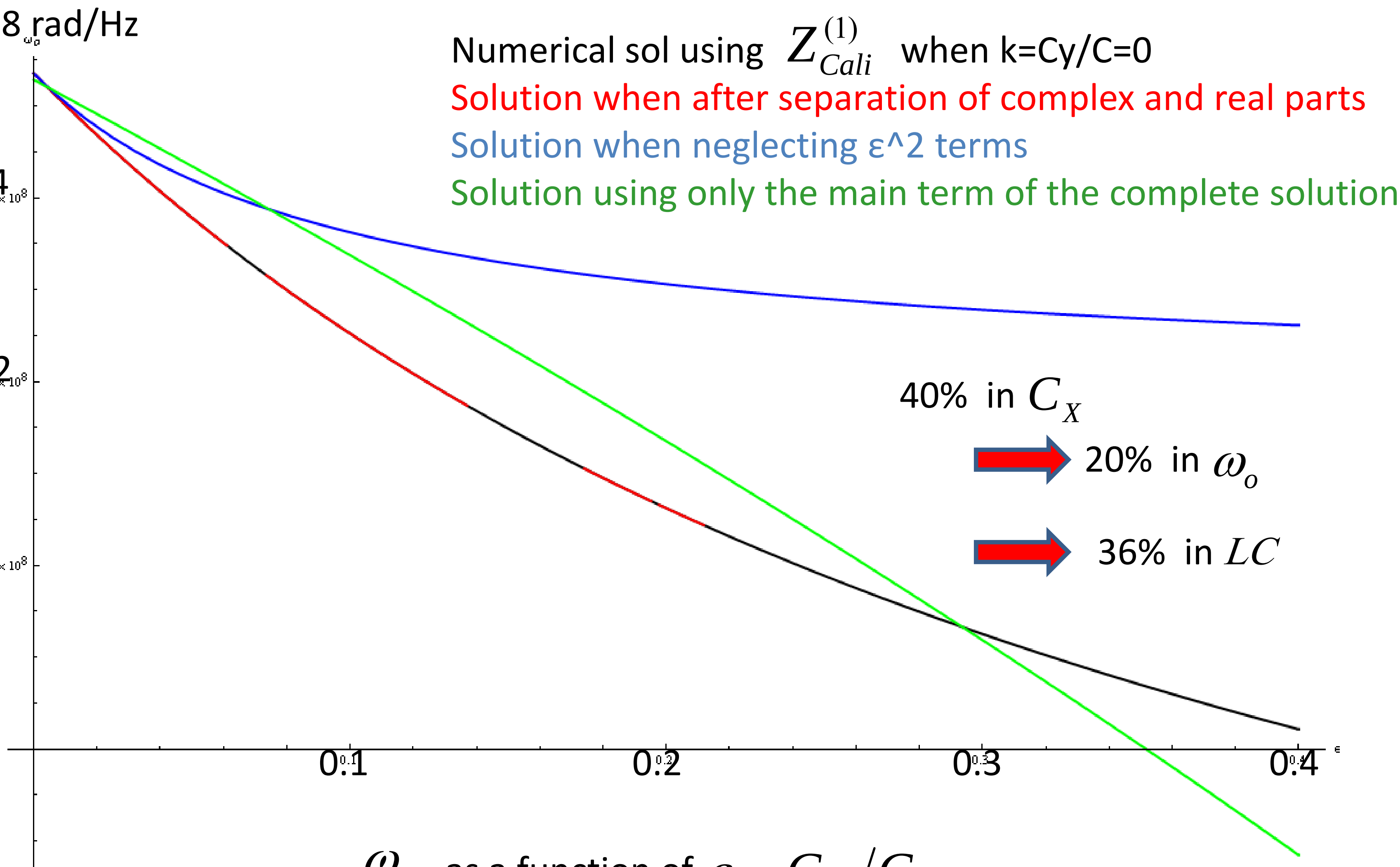
- Implementation of the new form of the $g^{MB\to\det}(s)$ in physics pulse prediction to consider the effects due to X-talk.
- Improvement of the measurement of cell energy.

Data Vs Transfer Function





Solving for ω



ω_o as a function of $\varepsilon = C_X / C$