First Look at EMEC Weights using the FFT Algorithm

Combined Test Beam Meeting

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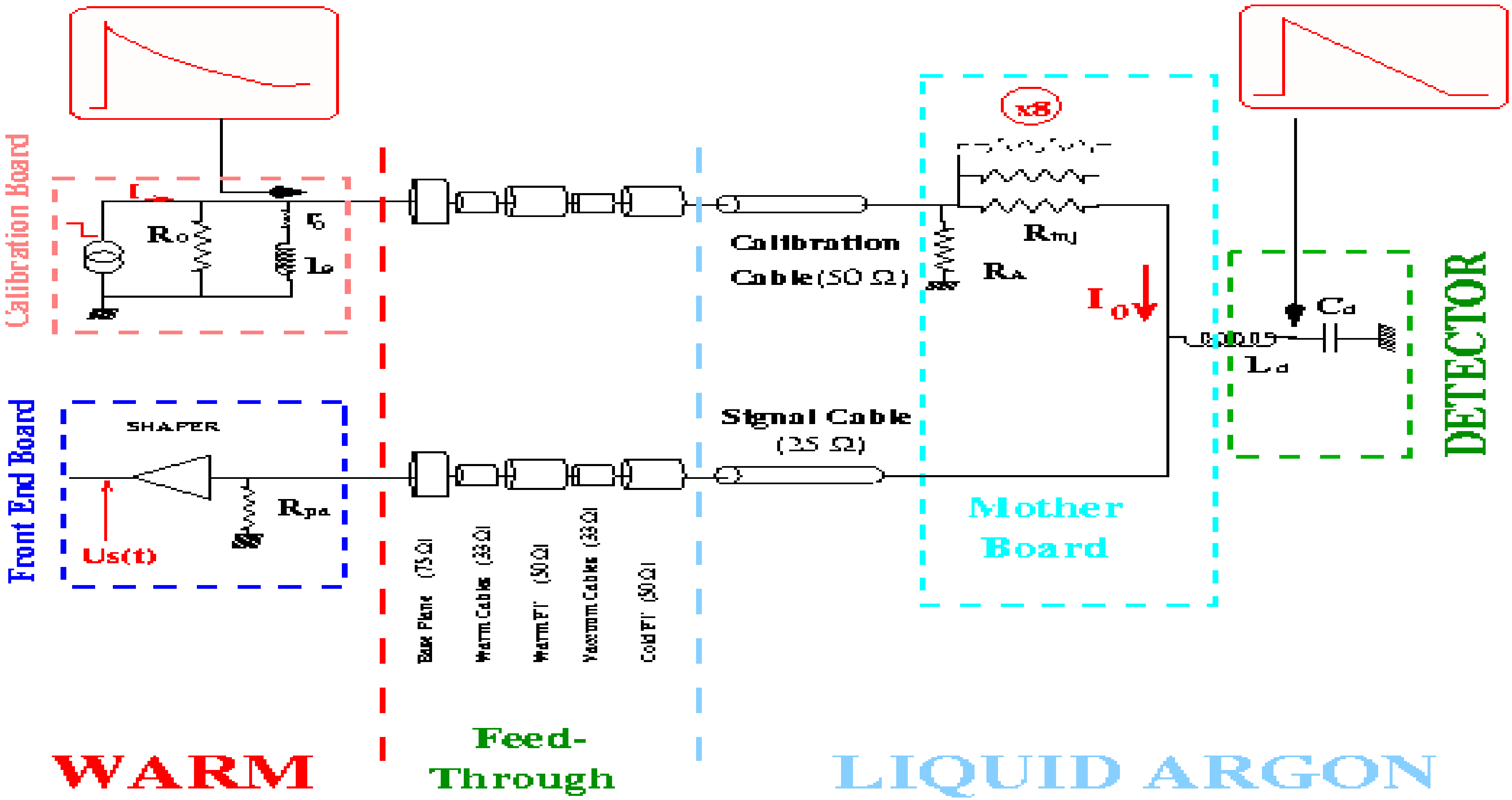
Overview

- Want to predict physics pulse shape from calibration pulse shape
  - Use this for determining “optimal” filtering weights
- At least two methods “on the market”
  - Time domain convolution
    - “NR” method Kurchaninov/Strizenec used in previous HEC analyses
  - Fourier transform “FFT” method
    - Neukermans, Perrodo, Zitoun, used in EM community
- Here we look at the FFT method for the EMEC in the 2002 combined run

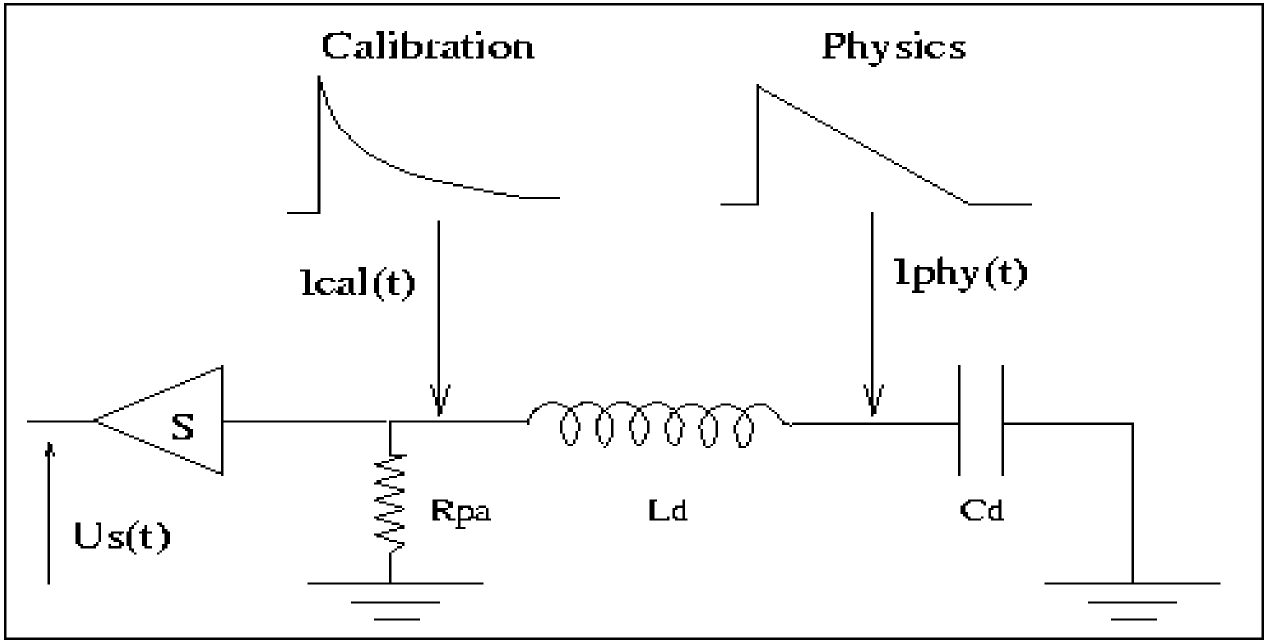
FFT Method I

- See: ATL-LARG-2001-008
  - Idea is to simplify the complicated picture:



FFT Method II

- Very simplified picture:



- Measure
  - Uphy(t)
  - Ucal(t)

- Calibration current:
  - ≈Exponential
  - Ical(t) $\propto$ Y (t) (α + (1-α)exp(-t/ τ_c))

- Physics current:
  - Triangle
  - Iphy(t) $\propto$ Y (t) Y(-t)(1-t/ τ_d))

FFT Method III

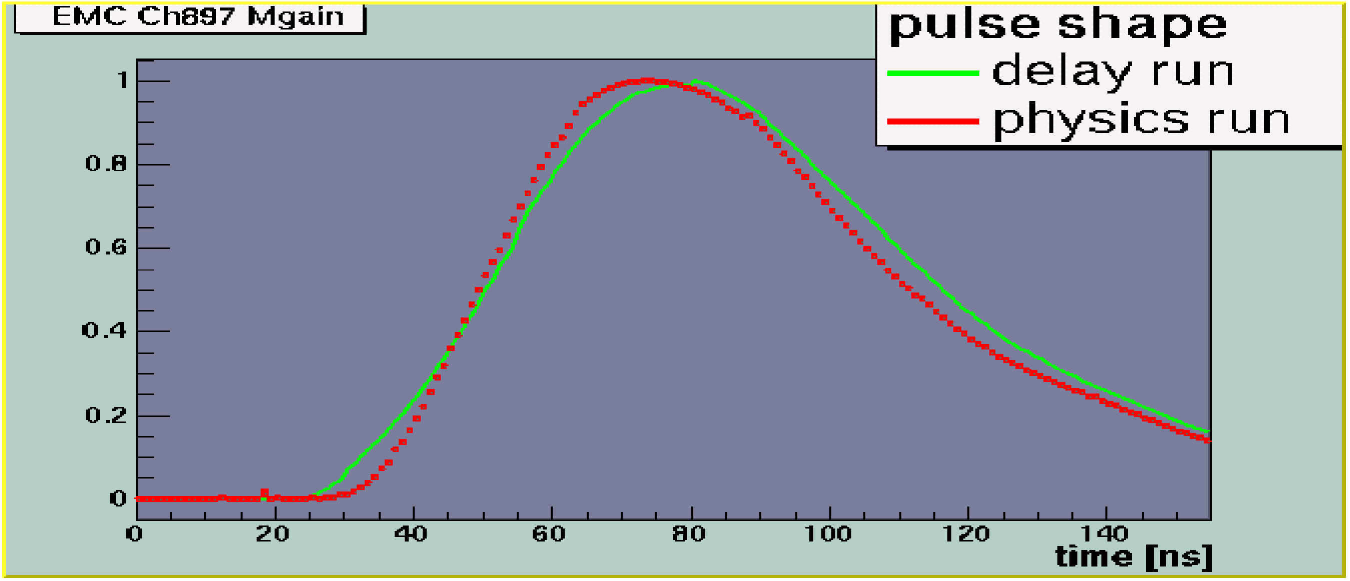
- **Use FT “transfer function” property:**
  - **Time Domain Convolution ⇔ Frequency Domain Multiplication**
- **Ingredients**
  - **Measured physics pulse shape Uphy(t) (take 128 samples in 1nsec bins)**
    - **Calculate (discrete) FFT[Uphy(t)] = DFT[Uphy](ω)**
    - **Assume: FT[Uphy](ω) = FT[Iphy](ω) x $H_{det}(\omega)$ x $H_{ro}(\omega)$**
  - **Measured calibration pulse shape from delay runs Ucal(t) (also 128 x 1 nsec)**
    - **Calculate (discrete) FFT[Uphy(t)] = DFT[Ucal](ω)**
    - **Assume: FT[Ucal](ω) = FT[Ical](ω) x $H_{cal}(\omega)$ x $H_{ro}(\omega)$**

FFT Method IV

- **Finally:**
  - $FT[Uphy](\omega) = FT[Ucal](\omega) \times G(\omega)$
- **In simple model:**
  - $G_{ana}(\omega) = FT[Iphy](\omega) / FT[Ical](\omega) \times \omega_0^2 / (\omega_0^2 - \omega^2)$
    - With $\omega_0^2 = 1 / LC$
- **Algorithm:**
  1) Measure Ucal(t) with delay run
  2) Calculate DFT[Ucal](ω)
  3) Predict FT[Uphy](ω)
     - 2 free parameters: LC and t_0(Iphy – Ical)
  4) Calculate predicted Uphy(t)
  5) Minimize predicted-measured Uphy(t)
     - Using uncorrelated χ^2 with unit error for now

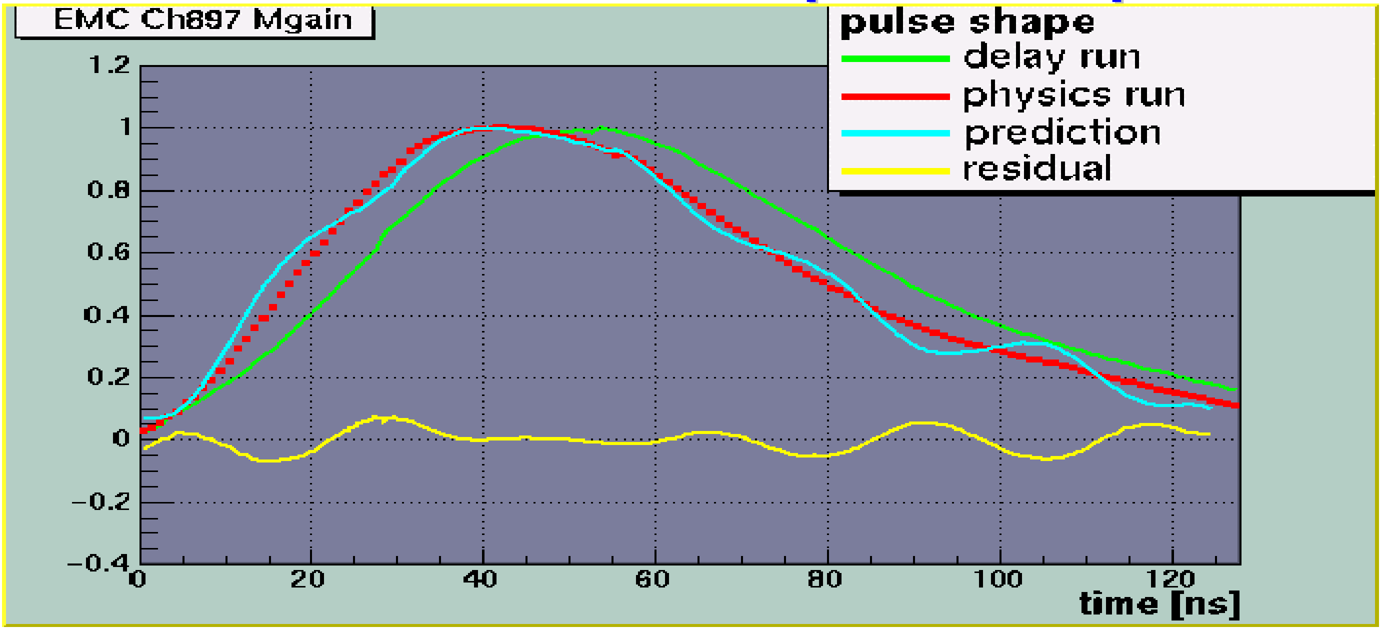
Data and Tools

- Physics and calibration data athena → root file
- In root: use "fftw" (http://www.fftw.org)
- Physics run: 13153 in middle gain
  - 120 GeV e, 20000 events
  - channel : 897 (η=8 ϕ=17 layer=2(middle))
  - E_{cubic}>0.4*Etot
  - TDC: wac=720, guard_region=20)
- Calibration run: 12836(middle gain)
  - DAC4000 - DAC10



First attempt at fit

- See oscillations in best predicted pulse:

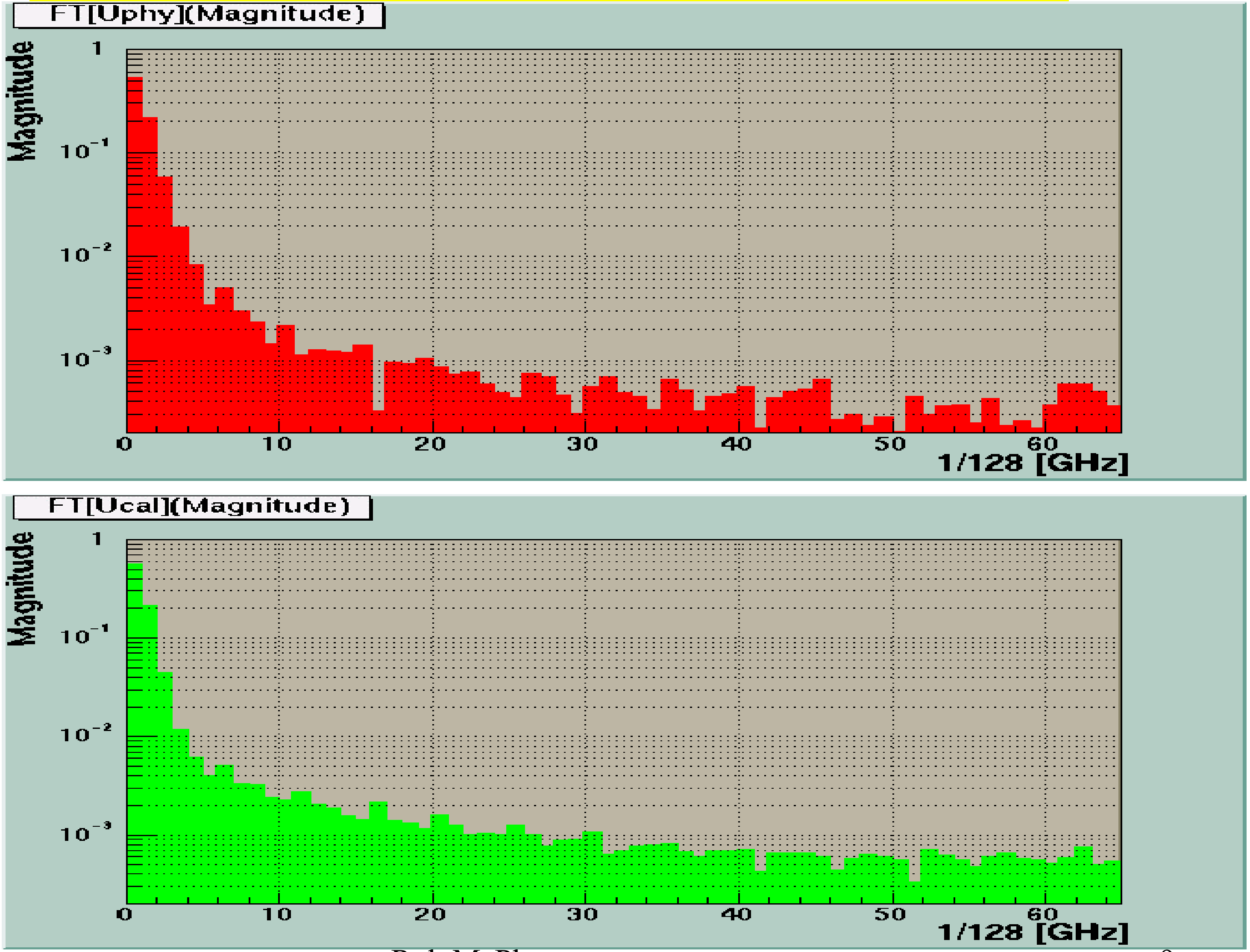


- Best parameters, fixed τ_d = 450 nsec, τ_c =370 nsec: (note: not yet fitted, just scanned and minimum found)
  - LC = 19.5 nHxnF
  - t_0 = 6.1 nsec
  - α = 0.075
  - Maximum residual: 7.1%

Look in frequency domain

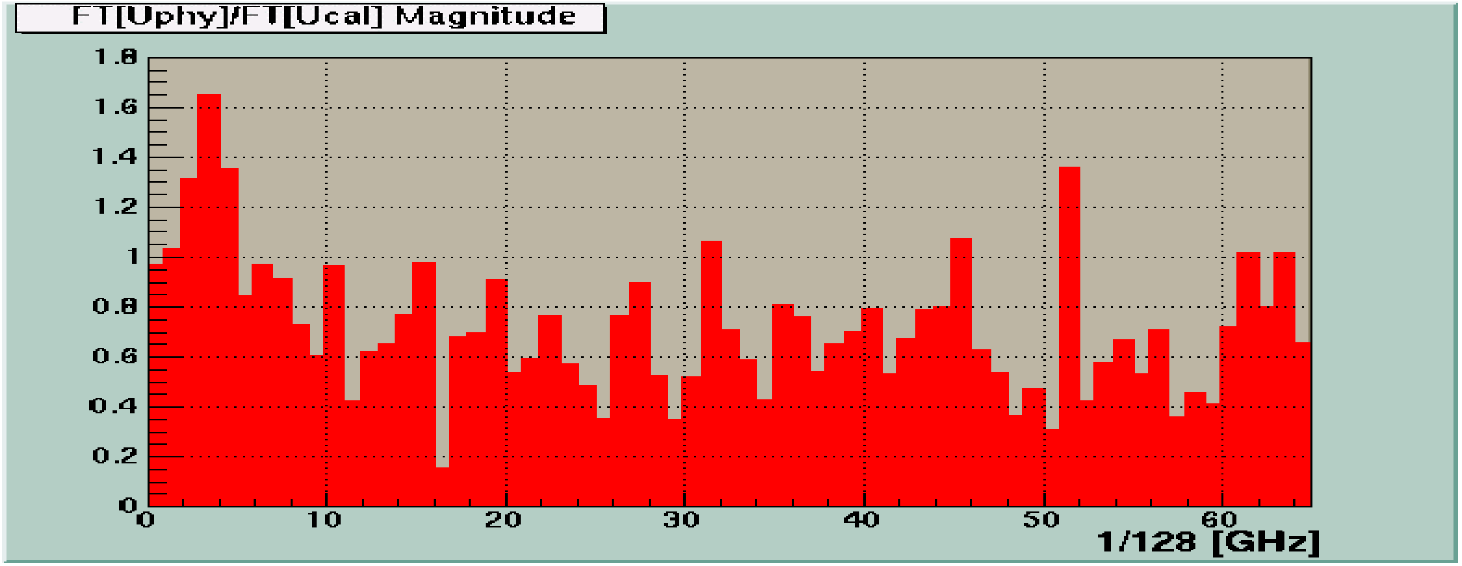
- PHYSICS
- 1 / f ???

CALIB

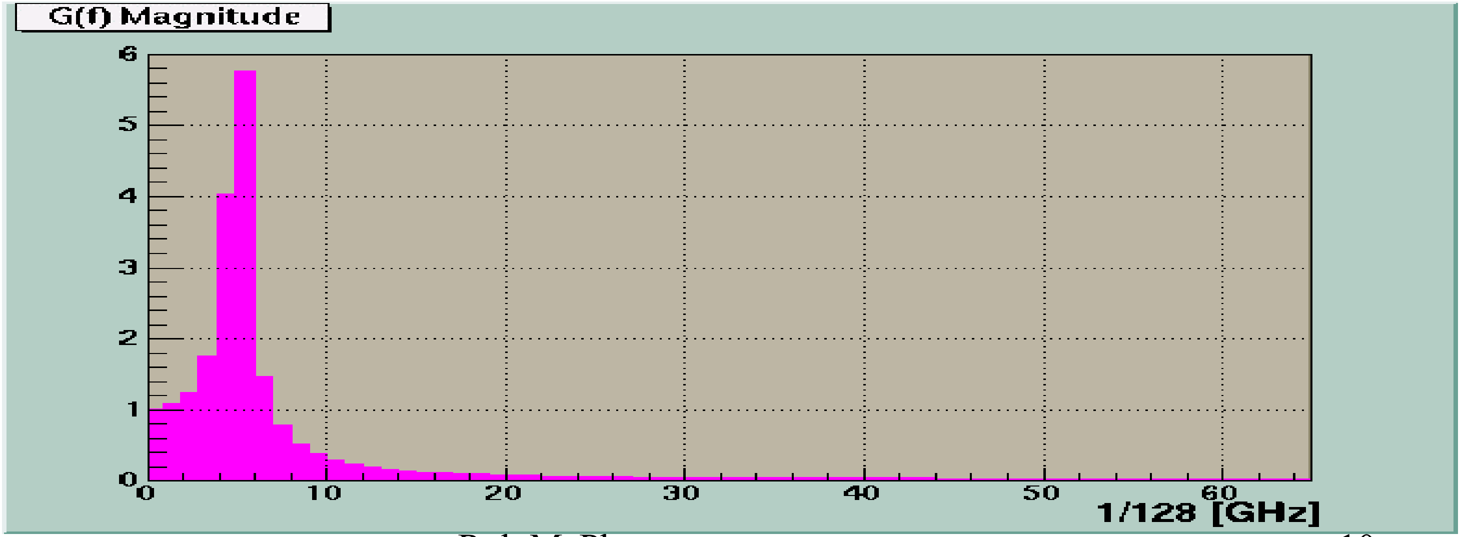


Transfer function G(f)

- Data
- $1 / f^2$???

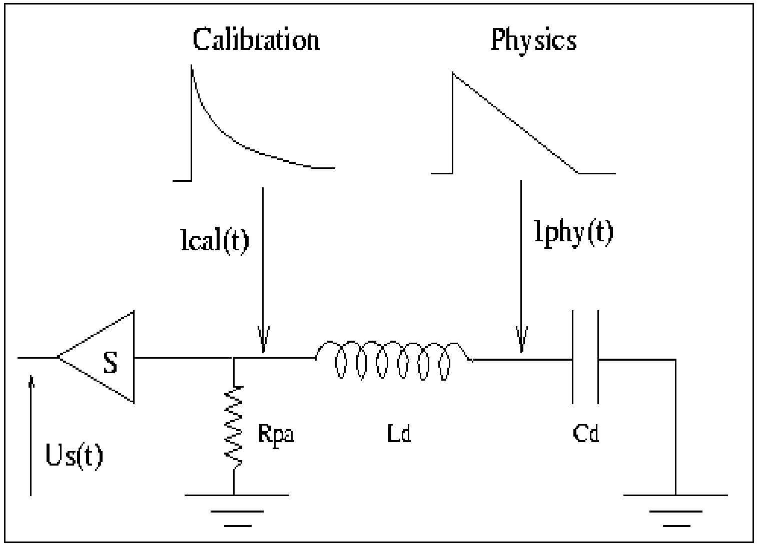


Analytic

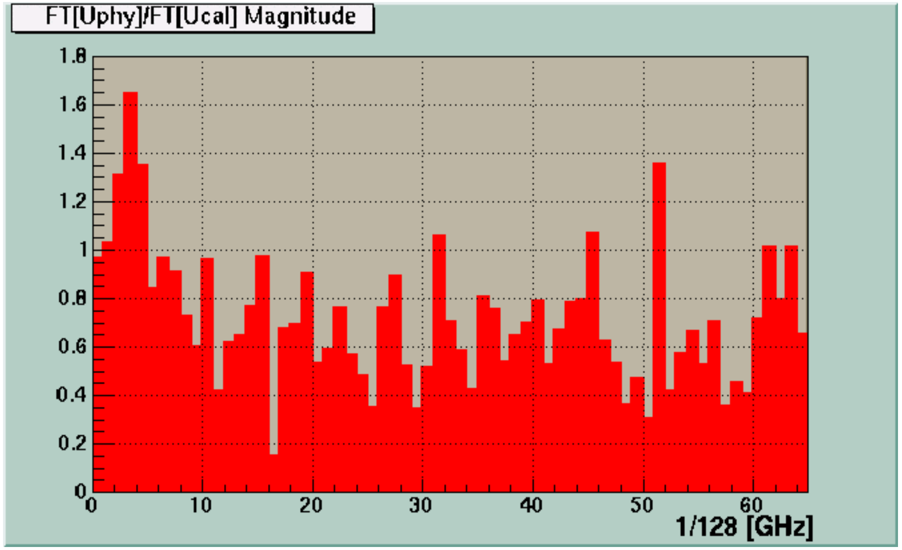


Flaw in the model or method?

- **Many theories:**
  - **Discrete FT windowing ⇒ leakage**
    - **Reduce pole height**
    - **Affect high/low frequency**
    - **But not an offset**
      - **Side note: the authors of this talk disagree on this point …**
  - **Or … maybe simple model not powerful enough?**

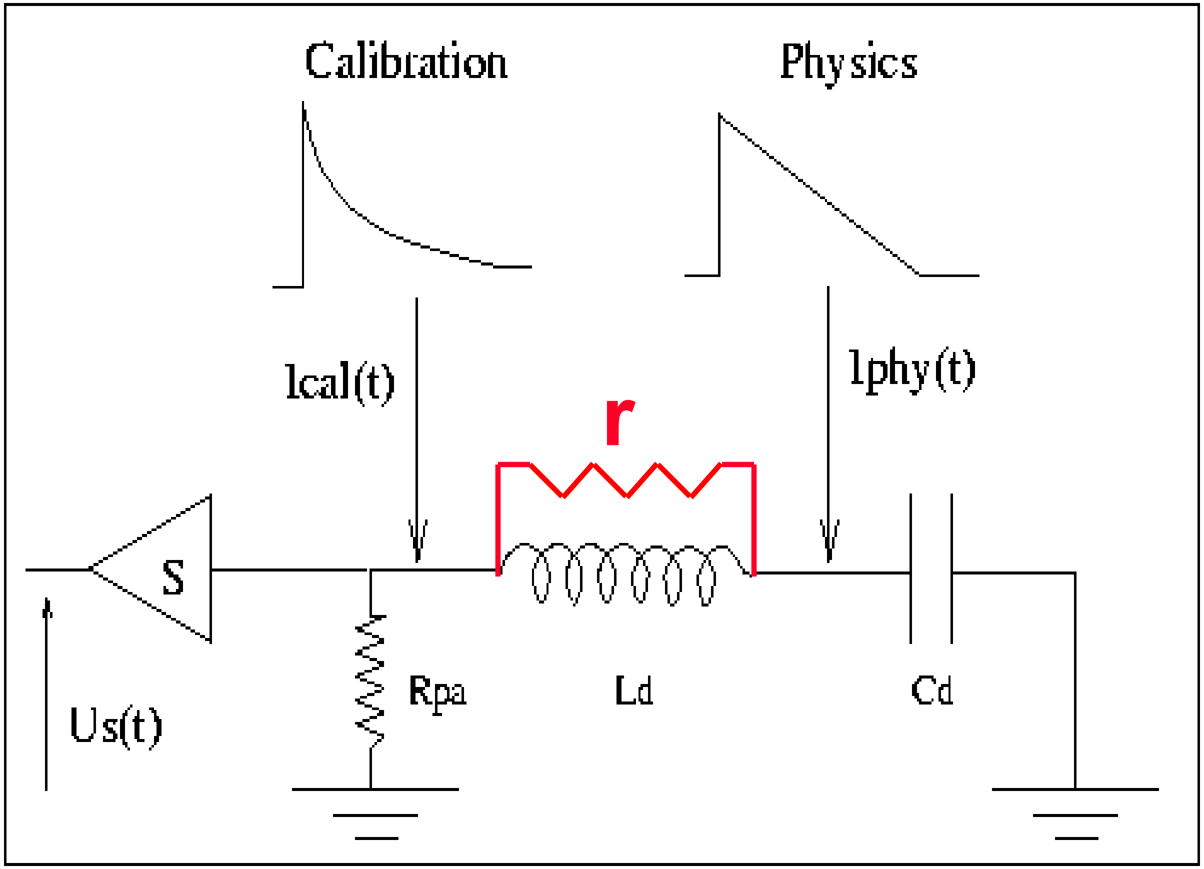


⇔ ?



Modified simple model

- Allow a high frequency physics tail with extra resistor:

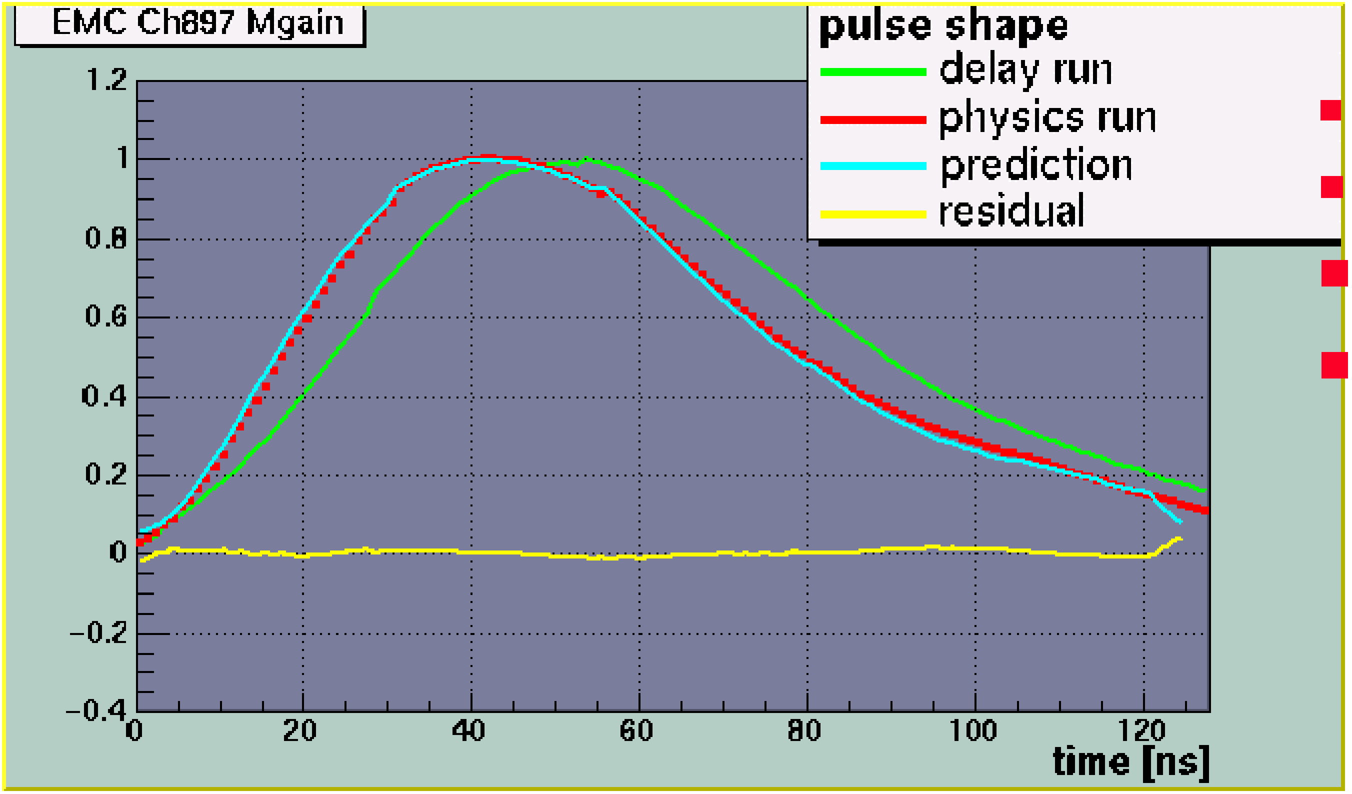


New G(ω) I

$$\frac{\omega_0^2}{(\omega_0^2 - \omega^2)} \rightarrow \frac{\omega_0^2 + j\omega/(rC)}{(\omega_0^2 - \omega^2) + j\omega/(rC)}$$

- With $\omega_0^2 = 1 / LC$
- New time constant $1/rC$

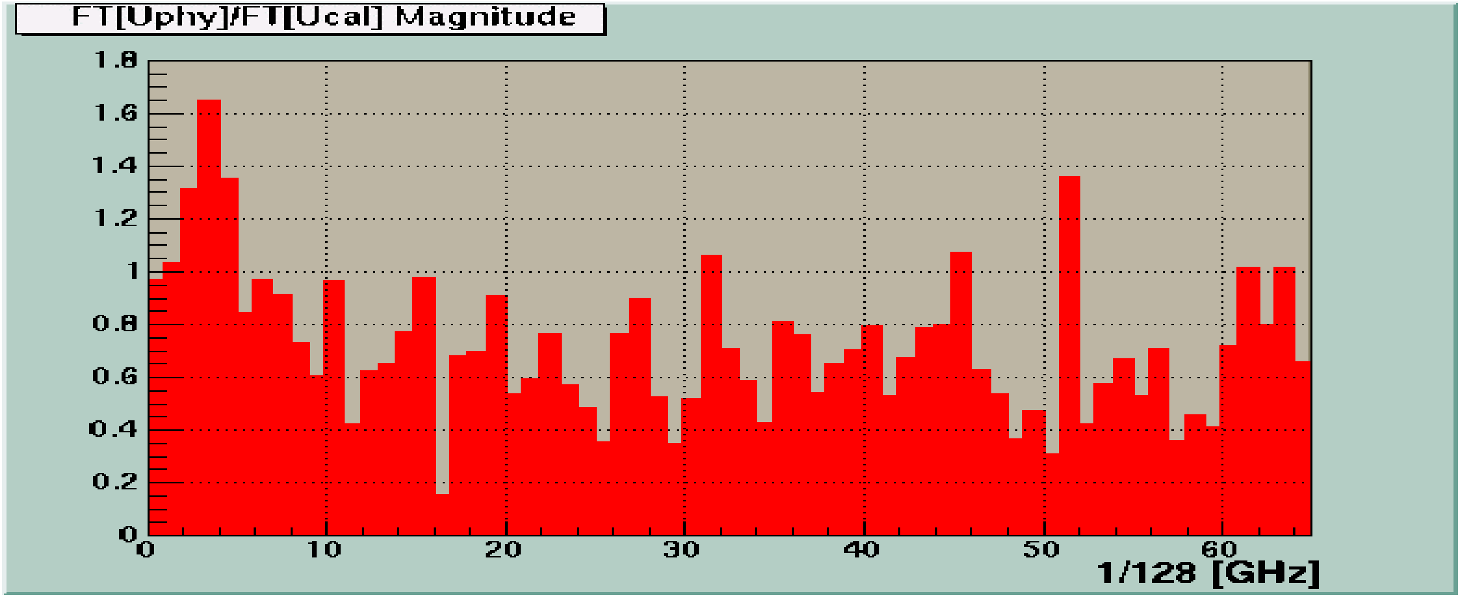
Best parameters (fixed τ_d = 450 nsec, τ_c =370 nsec):



- LC = 29.5 nHnF
- rC = 0.02 nsec
- t_0 = 0.5 nsec
- Maximum residual: 1.8% (t < 120 nsec)

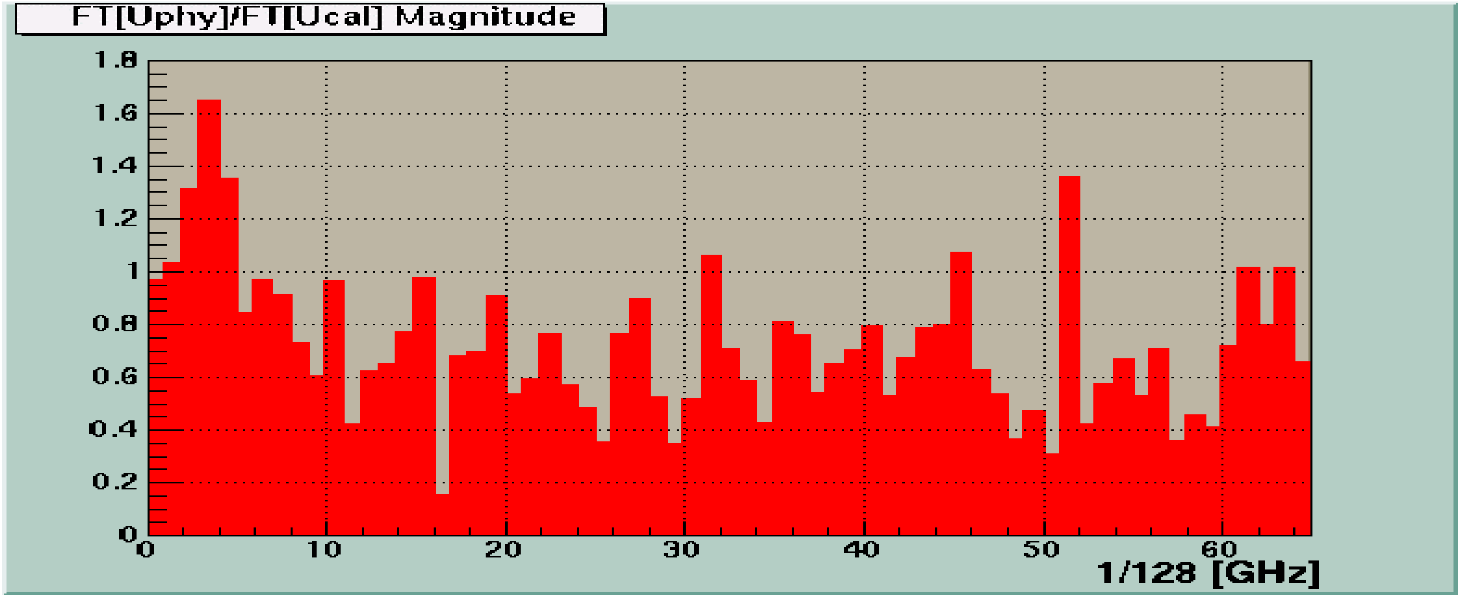
New G(ω) II

- **New fit:**
  - No visible oscillation
  - Fitted LC corresponds well with peak in FFT[Uphy] / FFT[Ucal
    - LC = 29.6 nHnF ⇒ f_0 = 0.0293 Hz = 3.74/128 Hz



Measure LC ? I

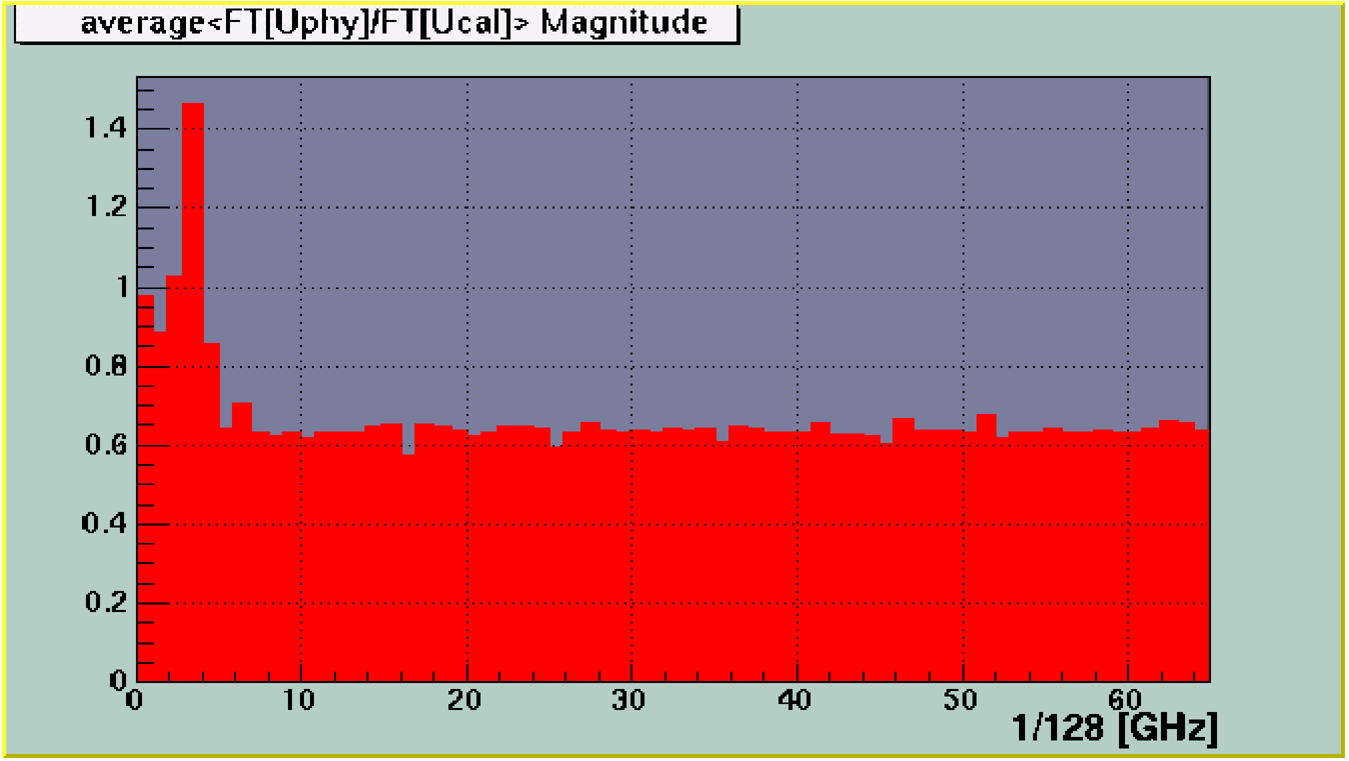
- In principle: instead of fit, can measure LC from:
  - FFT[Uphy] / FFT[Ucal]
- But the peak isn't obvious:



Can we do better?

Measure LC ? II

- Know from Fourier Transform theory
  - Time shift ⇔ Frequency oscillation
  - And we don't know t_0 very well
- Average over range of min time bins used in FFTs to smooth out oscillation (frequency pole is independent)



Recall:

"best" LC was 3.7/128

… seems promising

Conclusions

- Implemented FFT calibration for EMEC in combined run
- "out of the book" FFT method seems to have (known) problems
- EM community has some fixes that (I think) use more model parameters / complication
- Have instead made small change to the simple model (extra resistor in parallel with L)
- Seems to be a promising way of directly measuring LC with no fit at all!
- Next: will pursue as far as filtering weight calculation