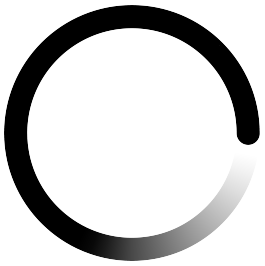
LAr calorimeter R&D for FCC-ee

Brief update on the noise

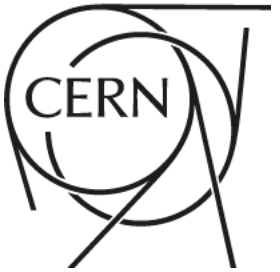
Brieuc François (CERN)

LAr Calo for FCC working meeting

April. 15th, 2021

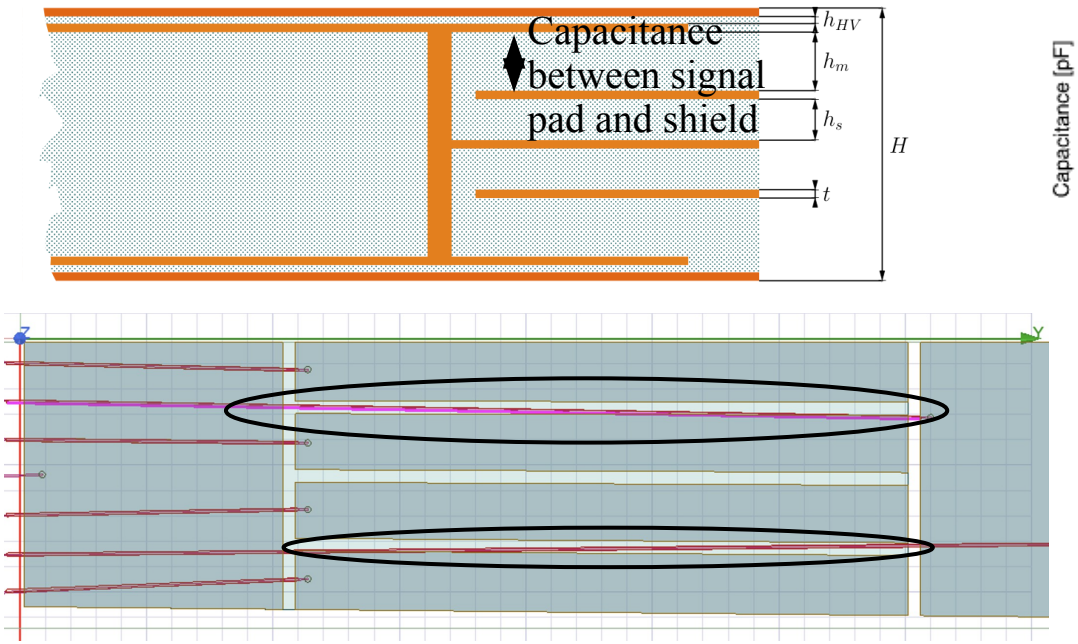


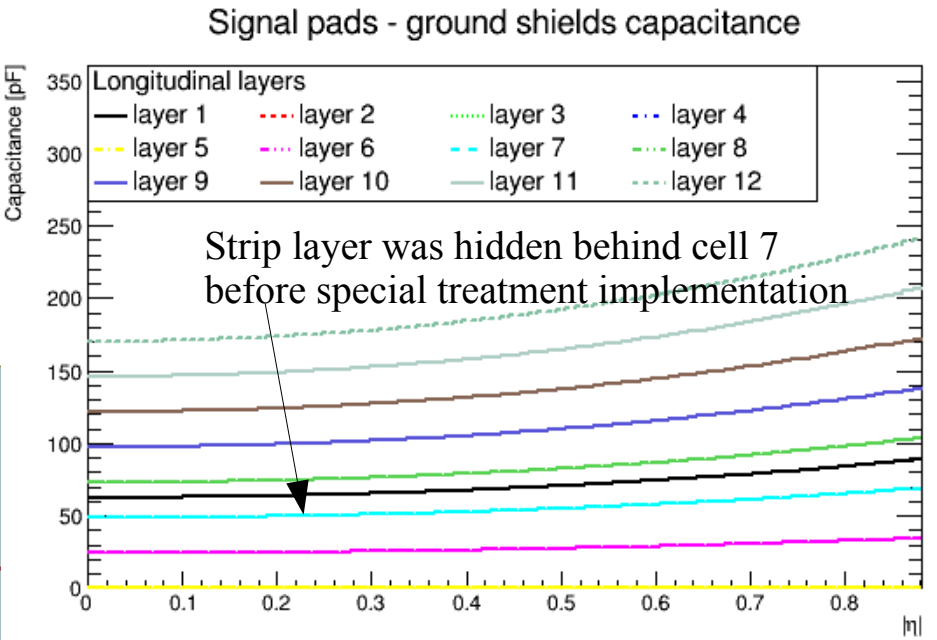
FUTURE CIRCULAR COLLIDER



Reminder

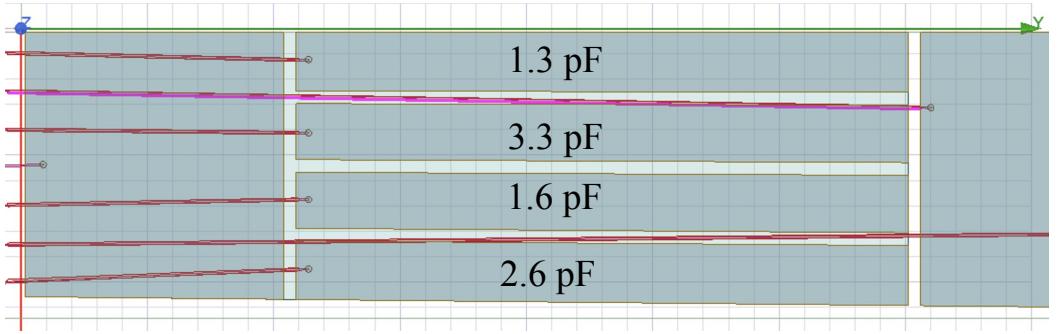
- Ground shield/Signal pad capacitance per unit length were obtained from Maxwell and extrapolated to the whole detector volume (see here)
- Special treatment needed for strip layer (layer 2) but was not implemented
  - Lower capacitance because shield run beneath the anti-etch

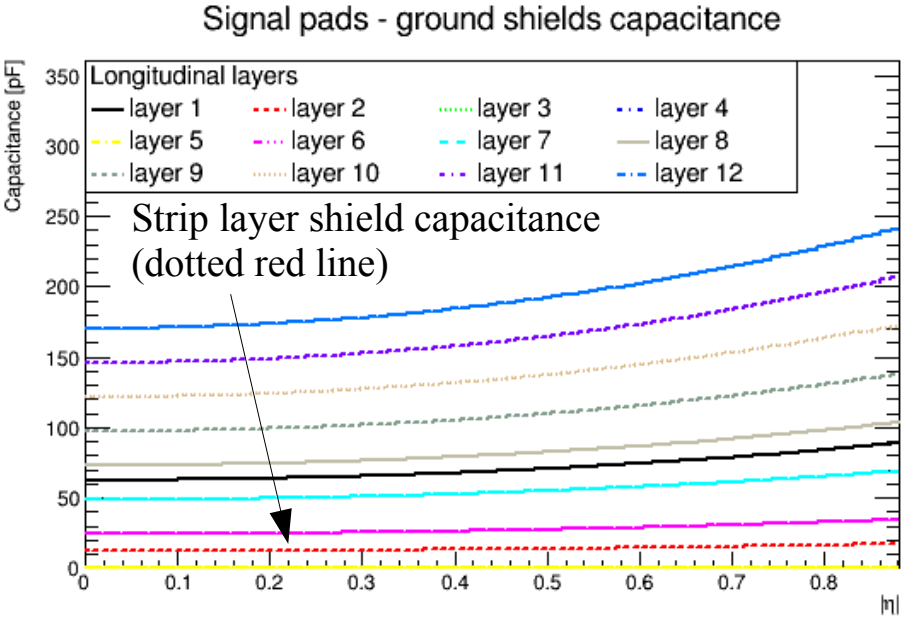




Shield capacitance

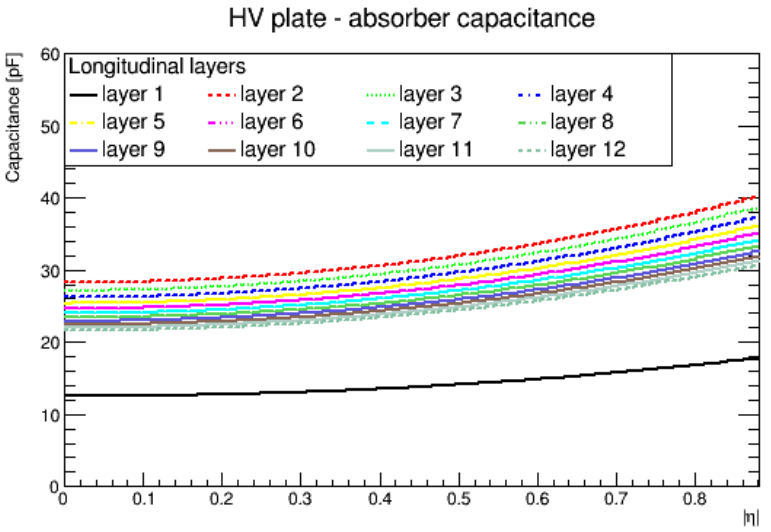
- Capacitance to shield for the strip layer
  - Depends on how the shield is centered w.r.t. the anti-etch
  - Not perfectly centered in this version of the Cadence drawing (will refine that for the next iteration)
- Still want a value per unit length (software flexibility)
  - Propose to take 3 pF / 48.43 mm for all of them → 0.062 pF/mm (regular cells: 0.123 pF/mm) to be on the safe side

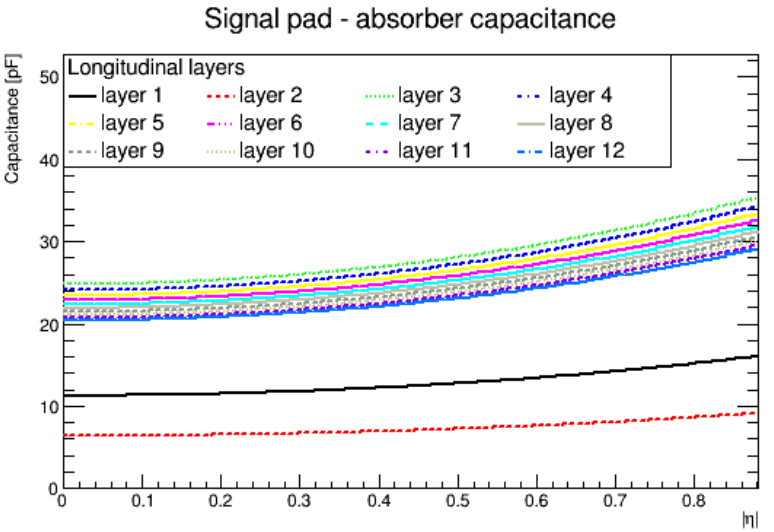




Total capacitance

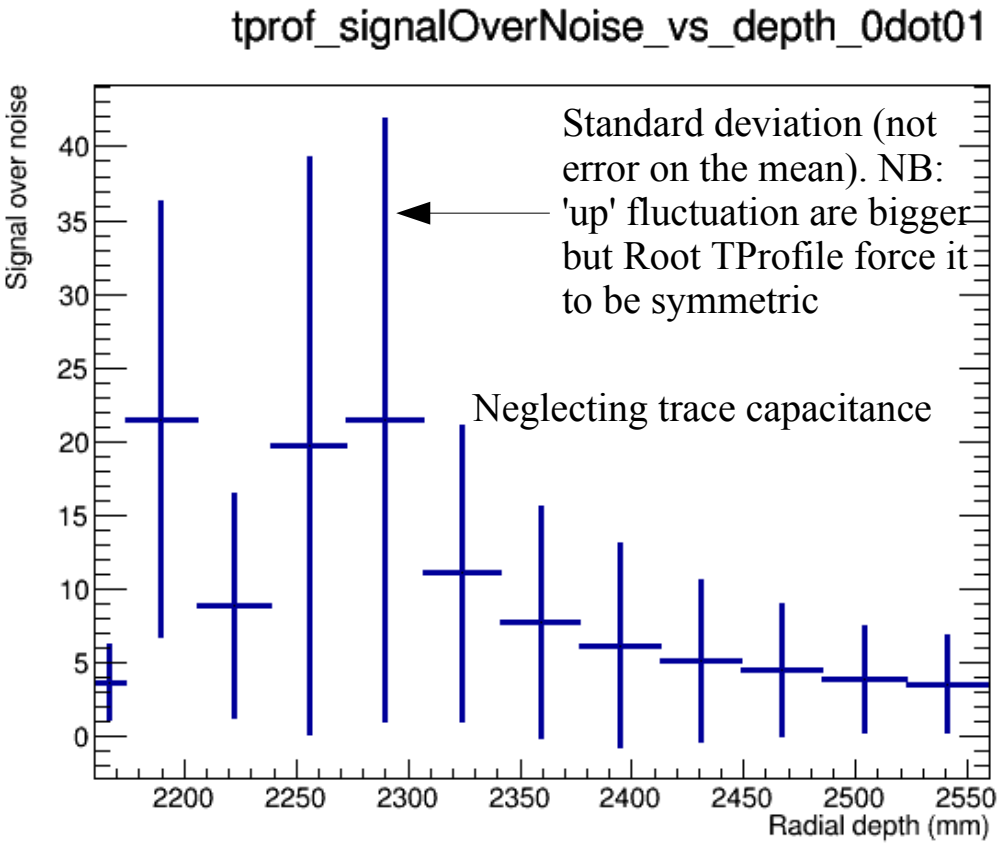
- $C_{total} = C_{shield} + C_{detector}$
  - $C_{detector}$ due to capacitance between signal plates and grounded absorber ~ 5 - 36 pF
    - Derived from analytical formula only – capacitance between two plates (less complex environment than for the shields)
    - Added the distance between HV plate and signal plate to the LAr gap, neglect the screening from HV plates (safe side)
    - Special prescription for the strip layer (divide capacitance by 4)
    - Decreases with increasing radius (compensating effects: larger LAr gap + bigger surface, larger LAr gap wins)



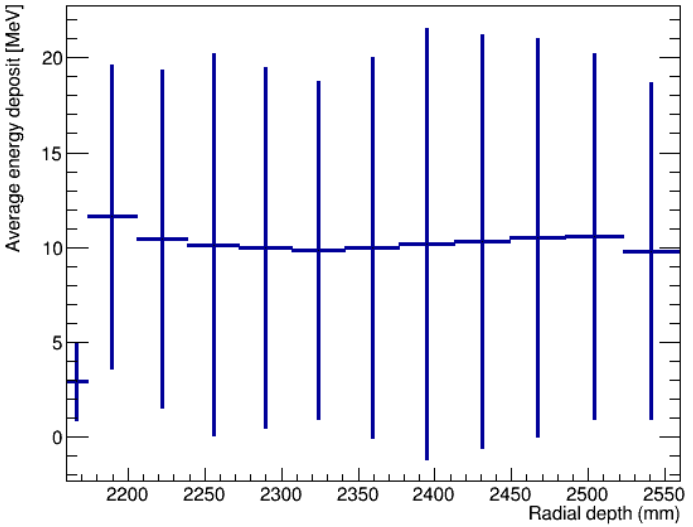


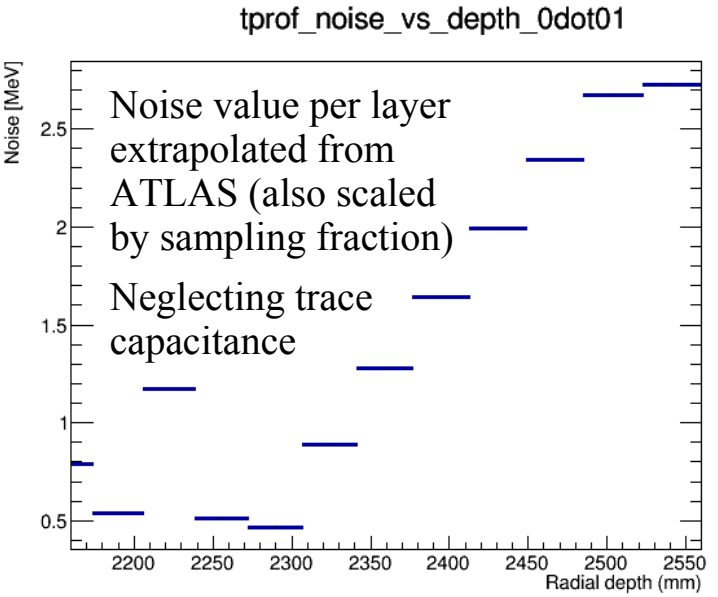
Can we see MIPs?

- MIP energy deposit per cell (Θ=90°)
  - No signal attenuation considered, no digitization (energy taken directly from Geant4 deposit and scaled with sampling fraction)



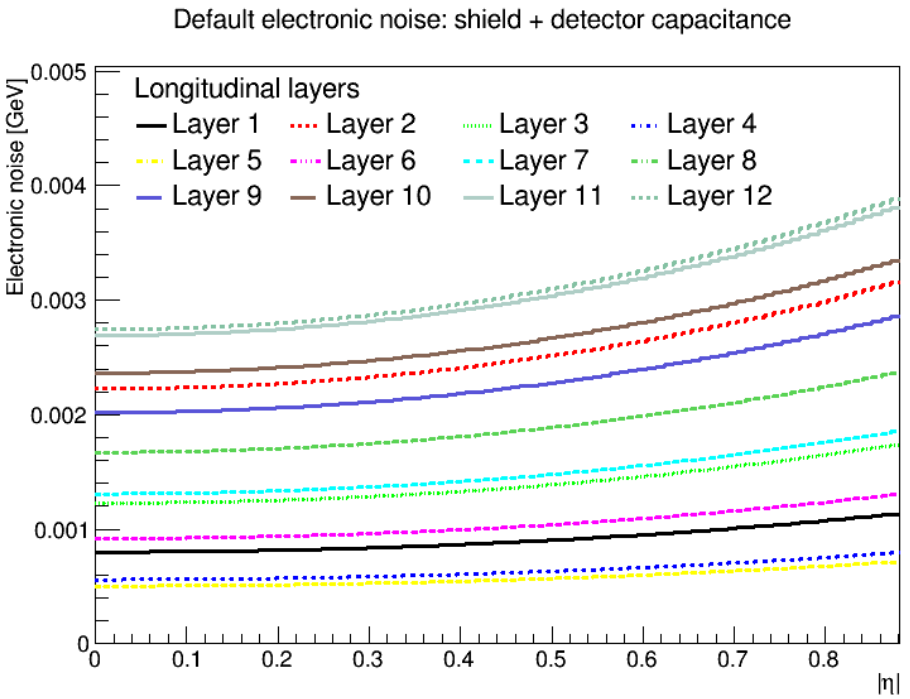
Average MIP energy deposit per layer

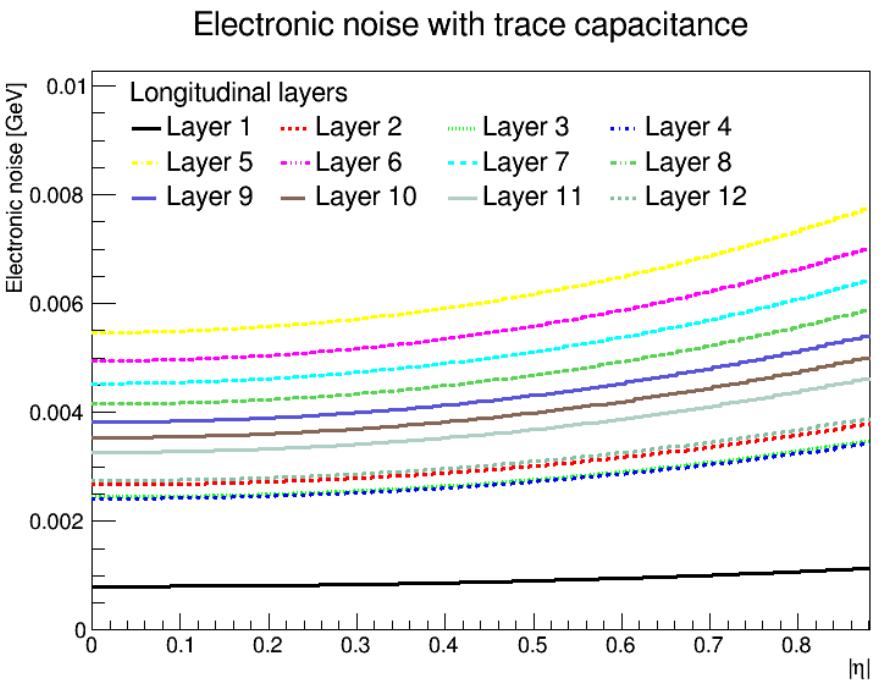




Noise from trace capacitance

- If noise from trace capacitance can not be neglected, it makes a difference
  - From 0.5 - 4 MeV to 0.8 – 8 MeV noise

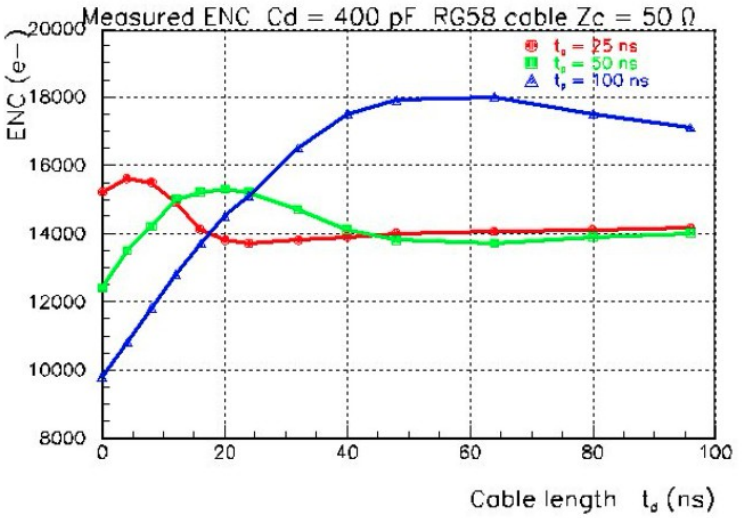




Noise from trace capacitance

- Conditions to neglect the noise contribution from the transmission line might be too restrictive for FCC-ee (where long shaping time is advantageous)
- Actually, even the noise contribution of the transmission line seen as coming from its capacitance seems to be an approximation not applicable if the shaping time is long*
  - Should investigate a more comprehensive description of the noise, including the whole readout
    - Based on formulas to start with, if possible
    - To be continued...

Noise VS transmission line length for different peaking times

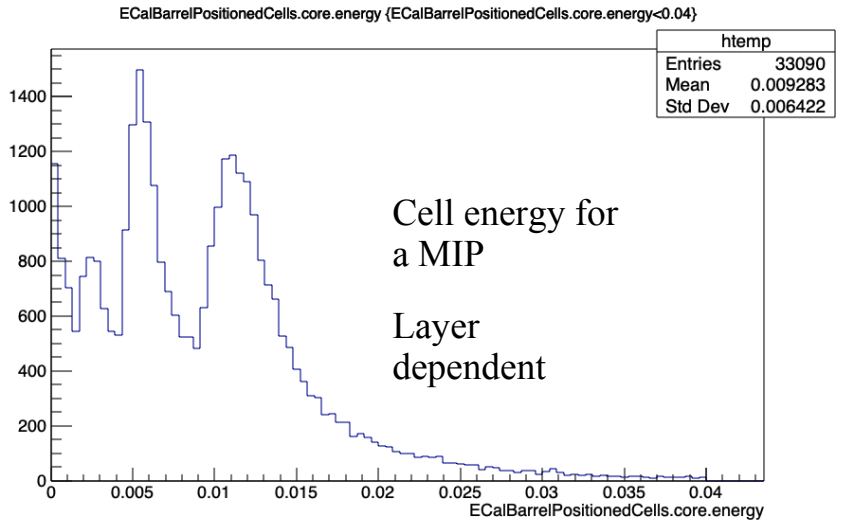


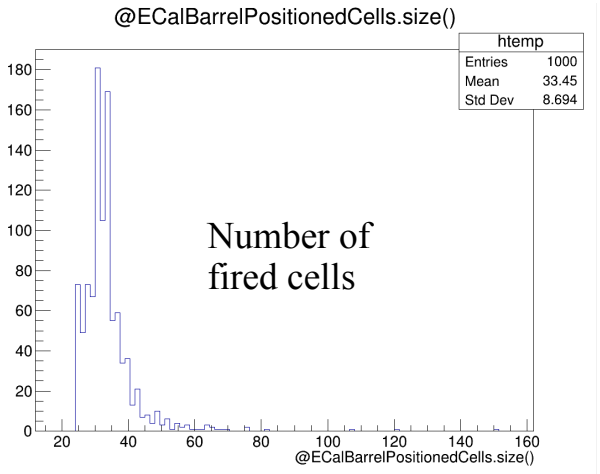
* From "Du LHC en general et de l'electronique en particulier" C. de La Taille

Additional material

Can we see MIPs?

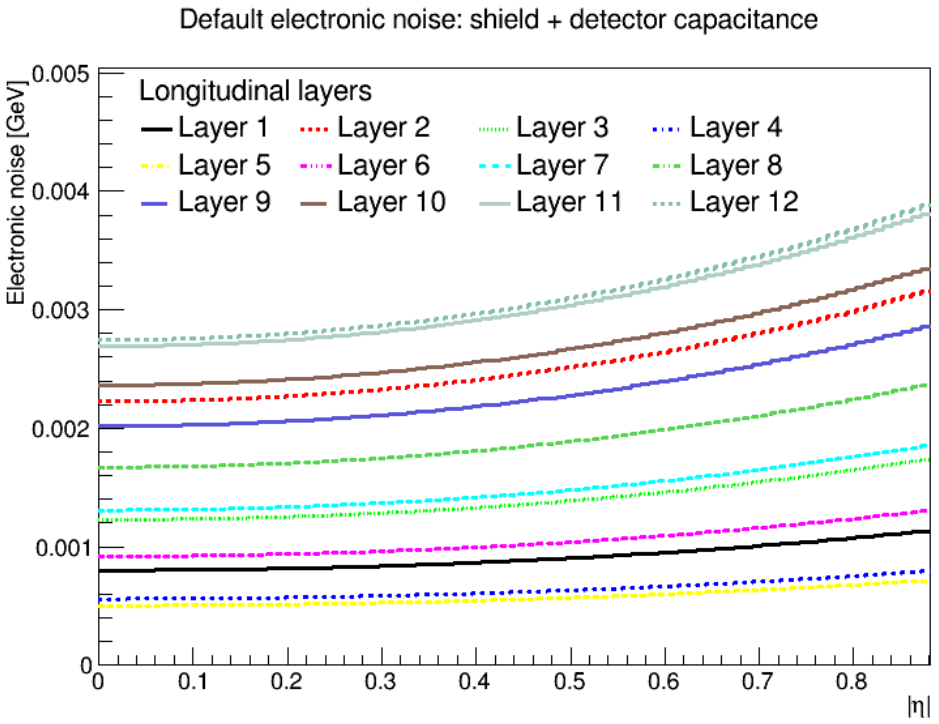
- MIP energy deposit per cell ($\Theta=90^{o}$)
  - No signal attenuation considered, no digitization (energy taken directly from Geant4 deposit and scaled with sampling fraction)





Noise estimation

- Noise estimation
  - Extrapolation from ATLAS noise/capa
  - 25 MeV for 1400 pF → 0.018 MeV/pF
  - Rescale by the sampling fraction ratio between ATLAS (0.18) and our per layer values
  - Result: 0.5 – 4 MeV noise



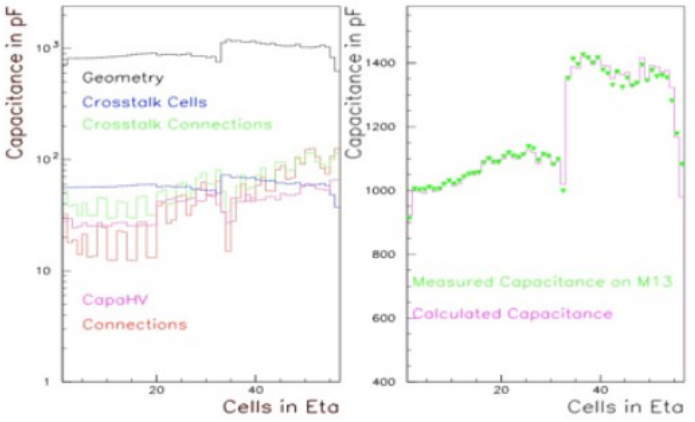
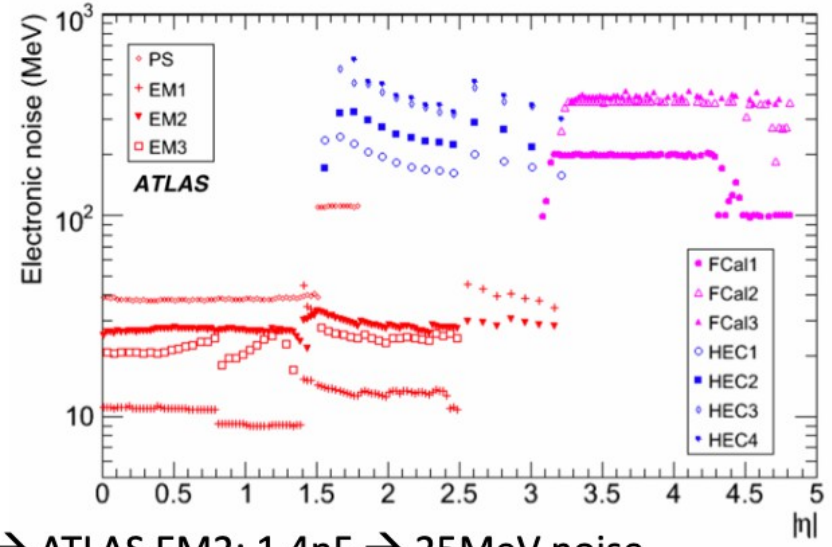


Figure 10: Left: expected contributions to cell capacitances as a function of η. Right: Total expected capacitance as a function of η and comparison with measurements done on M13 module. The agreement is very fair.

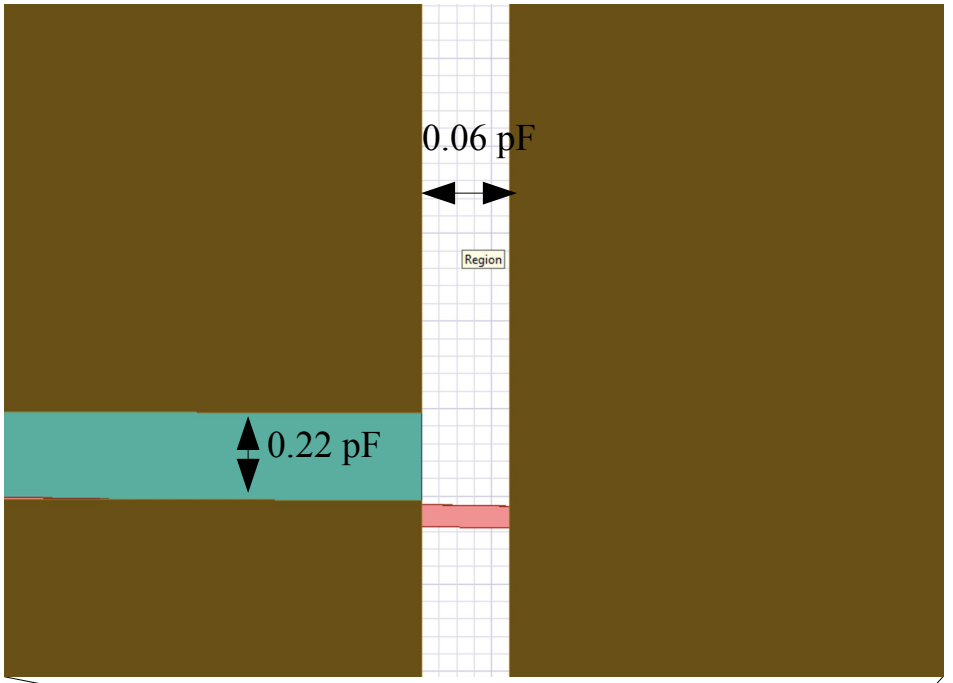
→ ATLAS middle cells (EM2): ε_r x 1nF = 1.4nF

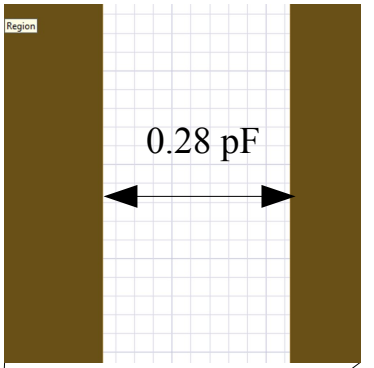


→ ATLAS EM2: 1.4nF → 25MeV noise

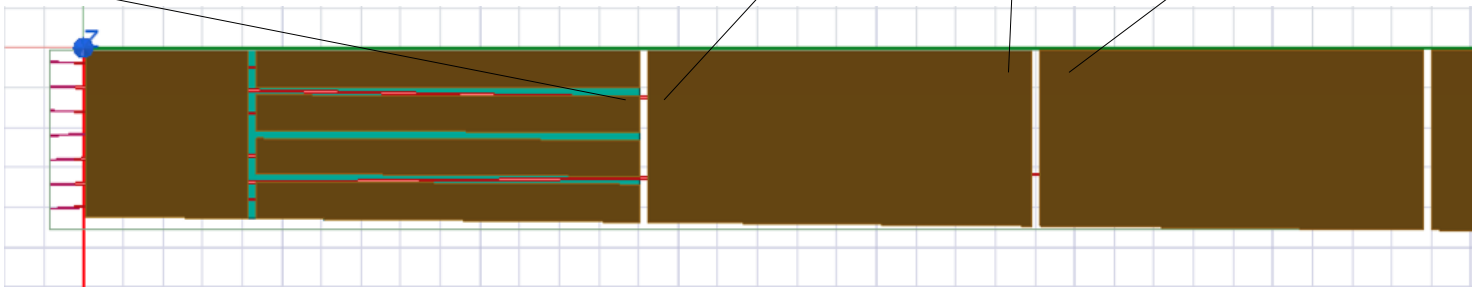
Capacitances between signal pads

- 1 mm 'horizontal' spacing between signal pads

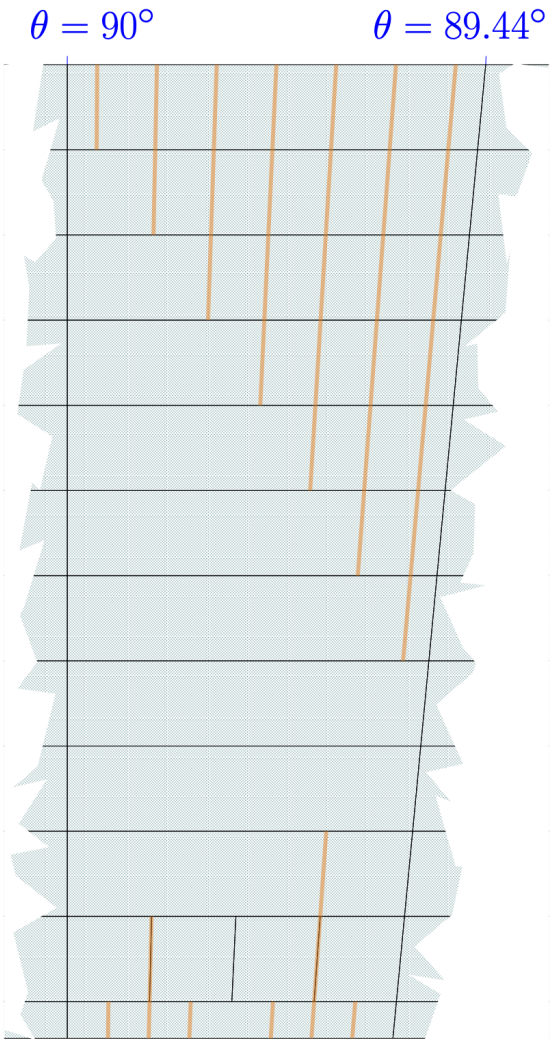




Signal pad top to signal pad bottom: ~40 pF



Readout electrodes



Readout electrodes