Electromagnetic calorimetry studies for the FCChh

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Outline

- Status of ECAL cells & reconstruction
- EM shower spread in B field
- ECAL energy resolution
- Empirical parameterizations for resolution
- Preliminary ECAL design constraints

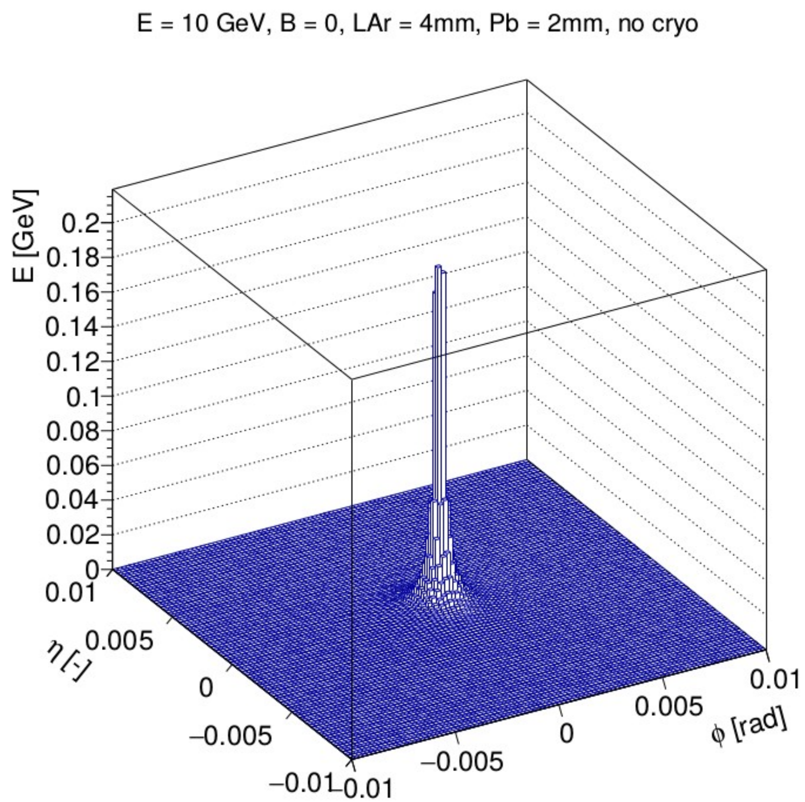
Calorimeter cells reconstruction

- Development of calorimeter cells reconstruction in FCC software (FCCSW)
  - Input: Geant4 hits
  - Output: cells with energy at EM scale
- Preparing following tools (work in progress)
  - Merge energy deposits in cells (defined by η-φ-r segmentation)
  - Calibrate cell energy to EM scale
    - Calibration constant (sampling fraction) depends on geometry (thickness of active/passive material)
  - Add noise to each cell
- Our needs from the FCCSW
  - Simulation: metadata to store info about simulation setup
  - Reconstruction: database (or dictionary) + services to add/read info for each cell (cell size, noise, coordinates)

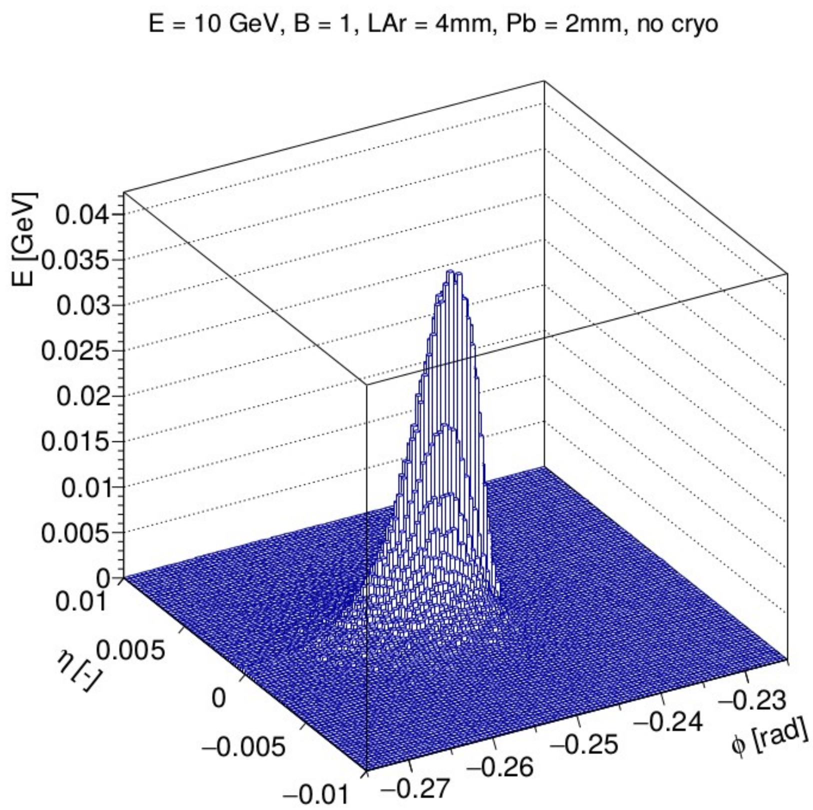
EM shower spread in B field

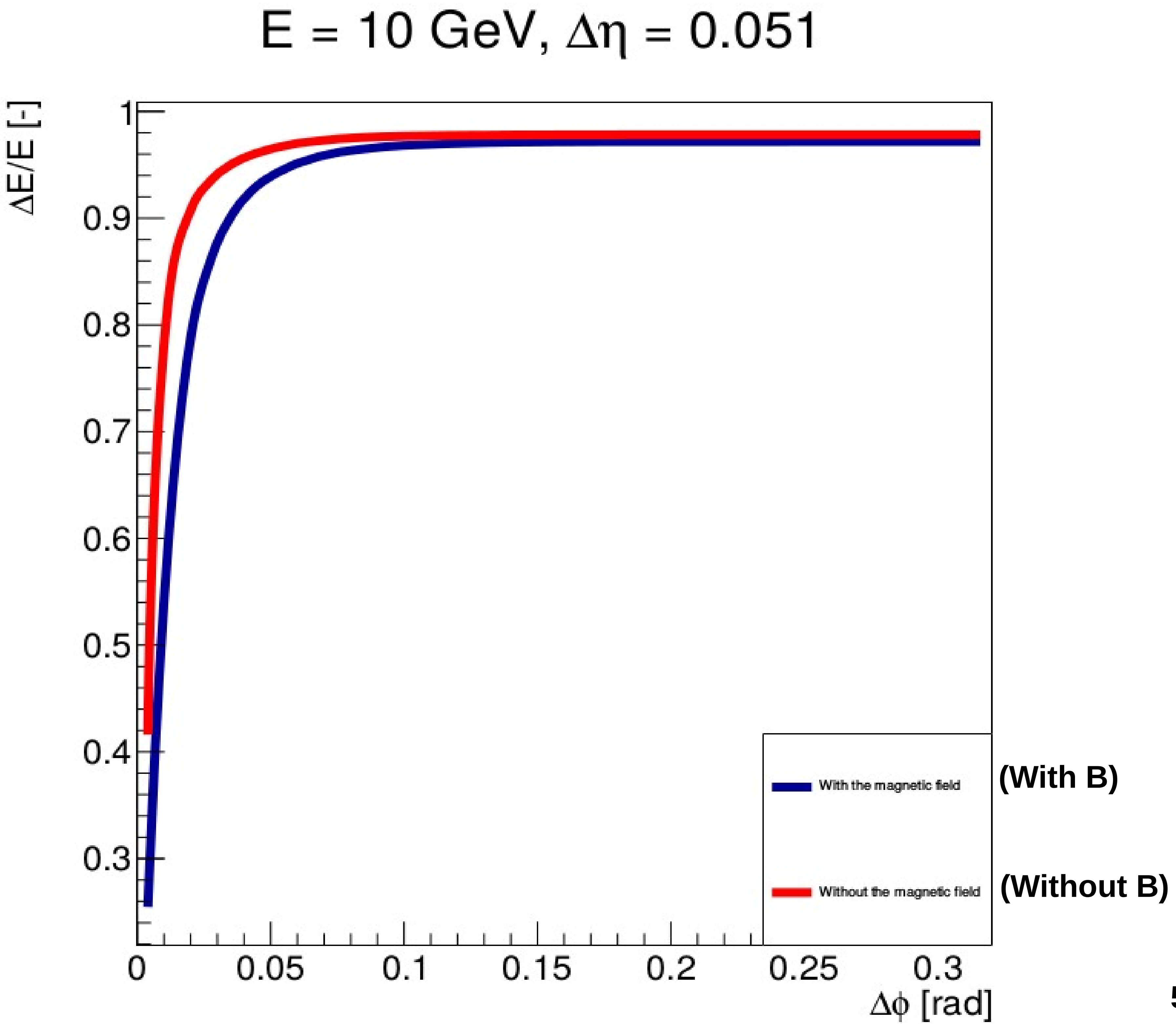
- Implemented simple clustering algorithm (sliding window)
- Determined the spread of the EM shower for 10 & 100 GeV single electrons in η and φ

Without *B* field



With *B* field





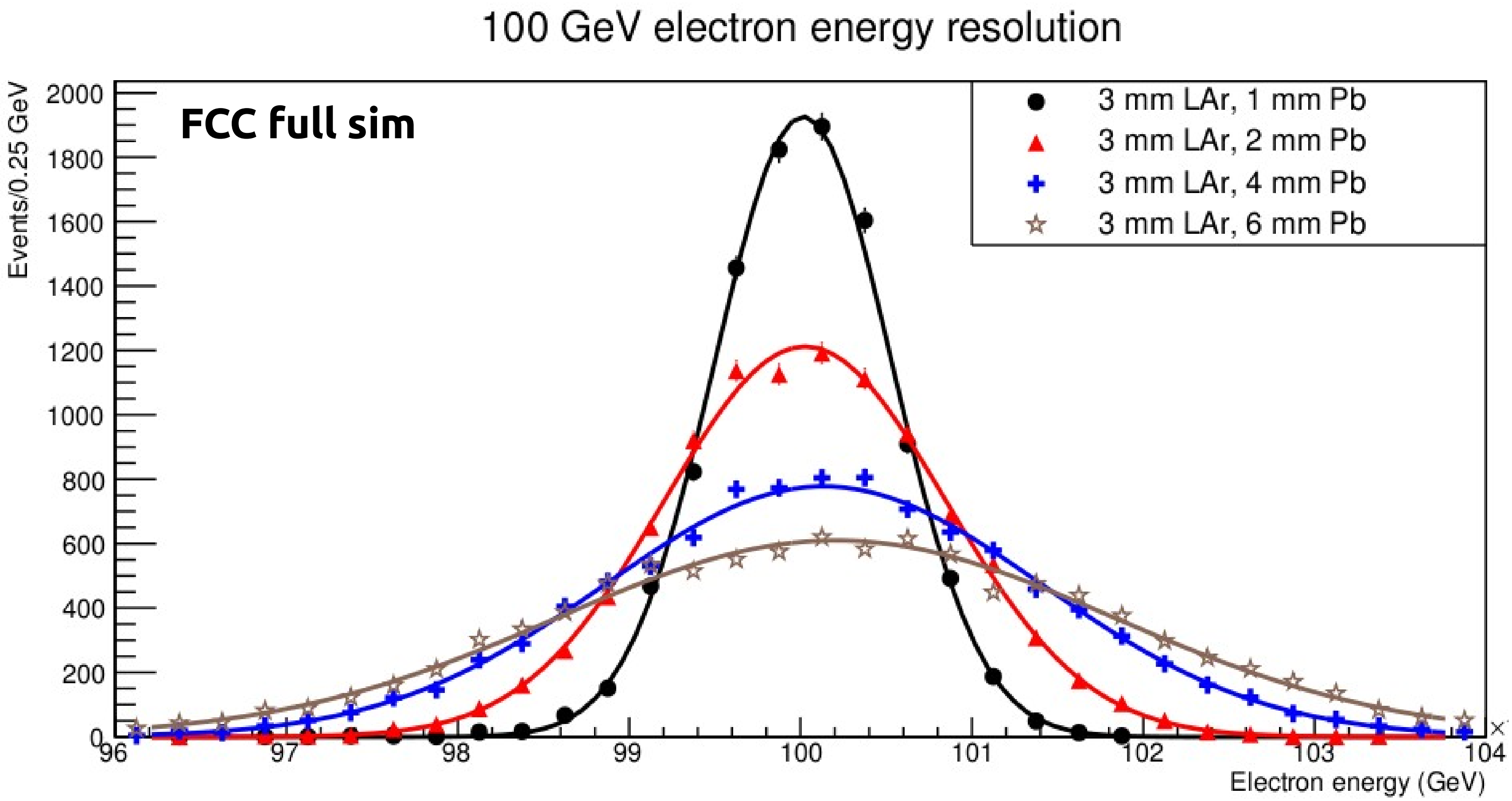
E = 10 GeV, Δη = 0.051
ΔE/E [-]
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0
0.05
0.1
0.15
0.2
0.25
0.3
Δφ [rad]
With the magnetic field
Without the magnetic field
(With B)
(Without B)

FCC ECAL full simulations

- Motivation: compare results of ECAL full simulations with empirical formulas for energy resolution
- Simplified detector geometry
  - Baseline FCChh ECAL dimensions (16m in z, and 2.7m < r < 3.4m)
  - Lead + LAr sampling calorimeter (~ATLAS)
  - Concentric cylinders of lead/LAr (const. thickness)
- Full simulation using official FCC software (FCCSW):
  - Generated single e- events at 20, 50, 100, 250, 500, 1000 GeV
  - 10 000 events at each energy, random in φ, and with $|\eta| < 0.1$
  - No cryostat, inner detector, or B field
  - Varied thickness of Pb/LAr layers

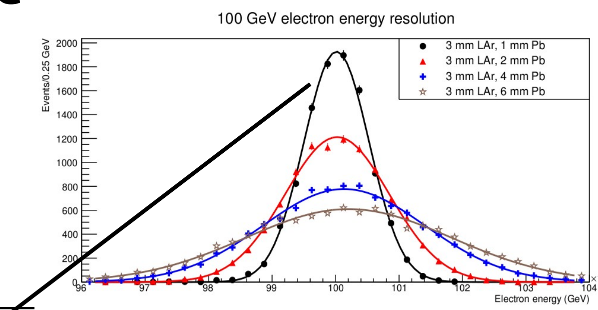
Energy resolution & absorber thickness

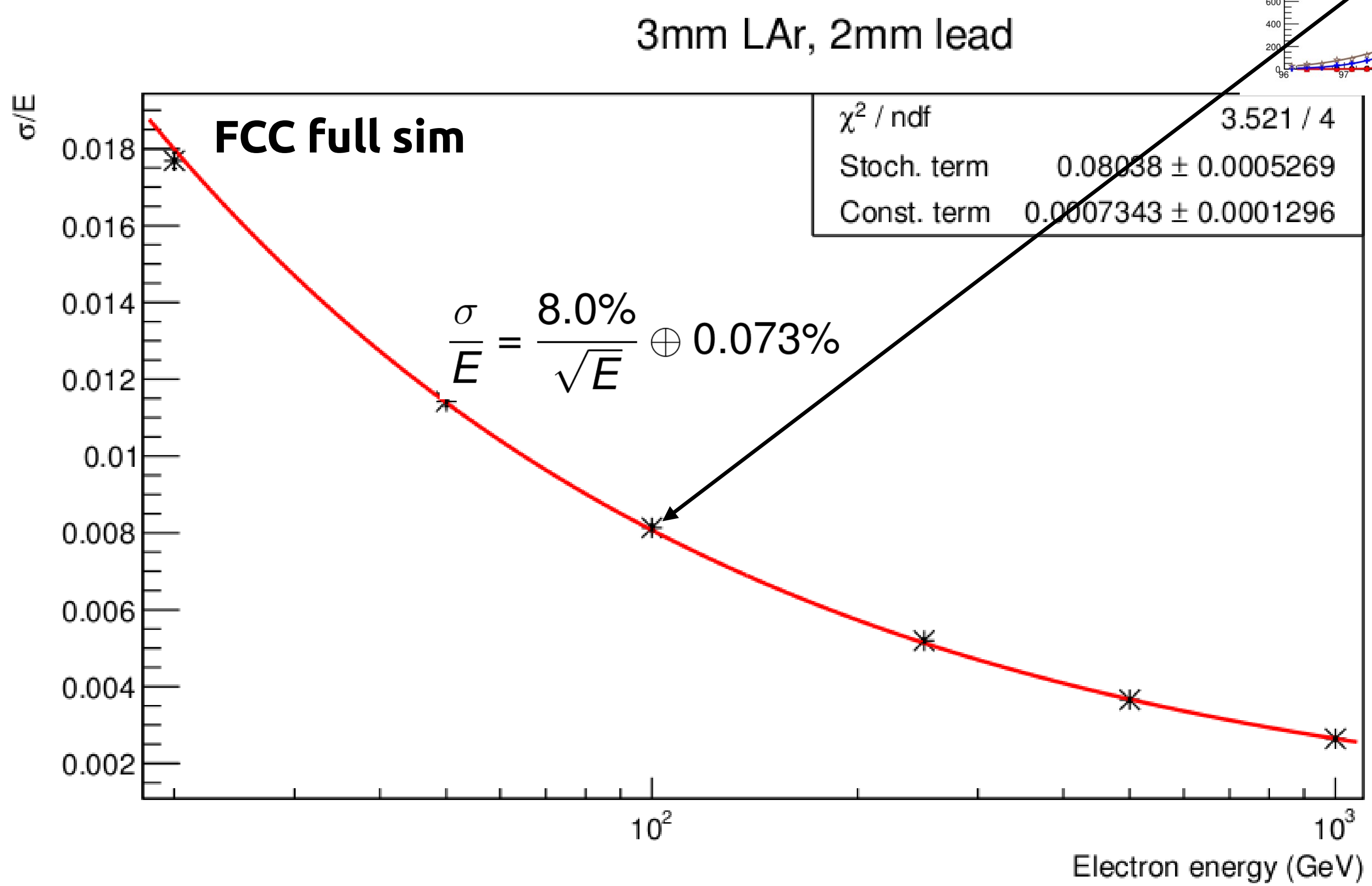
- As expected, resolution degrades with increasing Pb thickness (fluctuations become more significant)



ECAL resolution parameterization

- Standard 3-parameter formula $\frac{\sigma}{E} = \frac{a}{\sqrt{E}} \oplus \frac{b}{E} \oplus c$
  - Stochastic, noise, & constant terms, in quadrature
  - b → 0 (noise term)
  - Taking σ from the Gaussian fit to resolution





(Semi) empirical formulas for a

- Wigmans: $a_{samp} = 2.7\% \sqrt{\frac{d_{active}}{f_{samp}}}$ $\frac{1}{f_{samp}} = 1 + \frac{E_{absorber}}{E_{active}}$ (for Mips)

Wigmans, *Calorimetry: Energy Measurement in Particle Physics* (2000)

- Rossi approximation B: $a_{samp} = 3.2\% \sqrt{\frac{E_C \cdot d_{abs}}{F \cdot X_0 \cdot \langle \cos\theta \rangle}}$

$$\langle \cos\theta \rangle \approx \cos\left(\frac{21 MeV}{\pi E_c}\right)$$

$$F(z) = \left(1 + z \log\left(\frac{z}{1.526}\right)\right) e^z \qquad z = 2.29 \cdot \frac{1 MeV}{E_c}$$

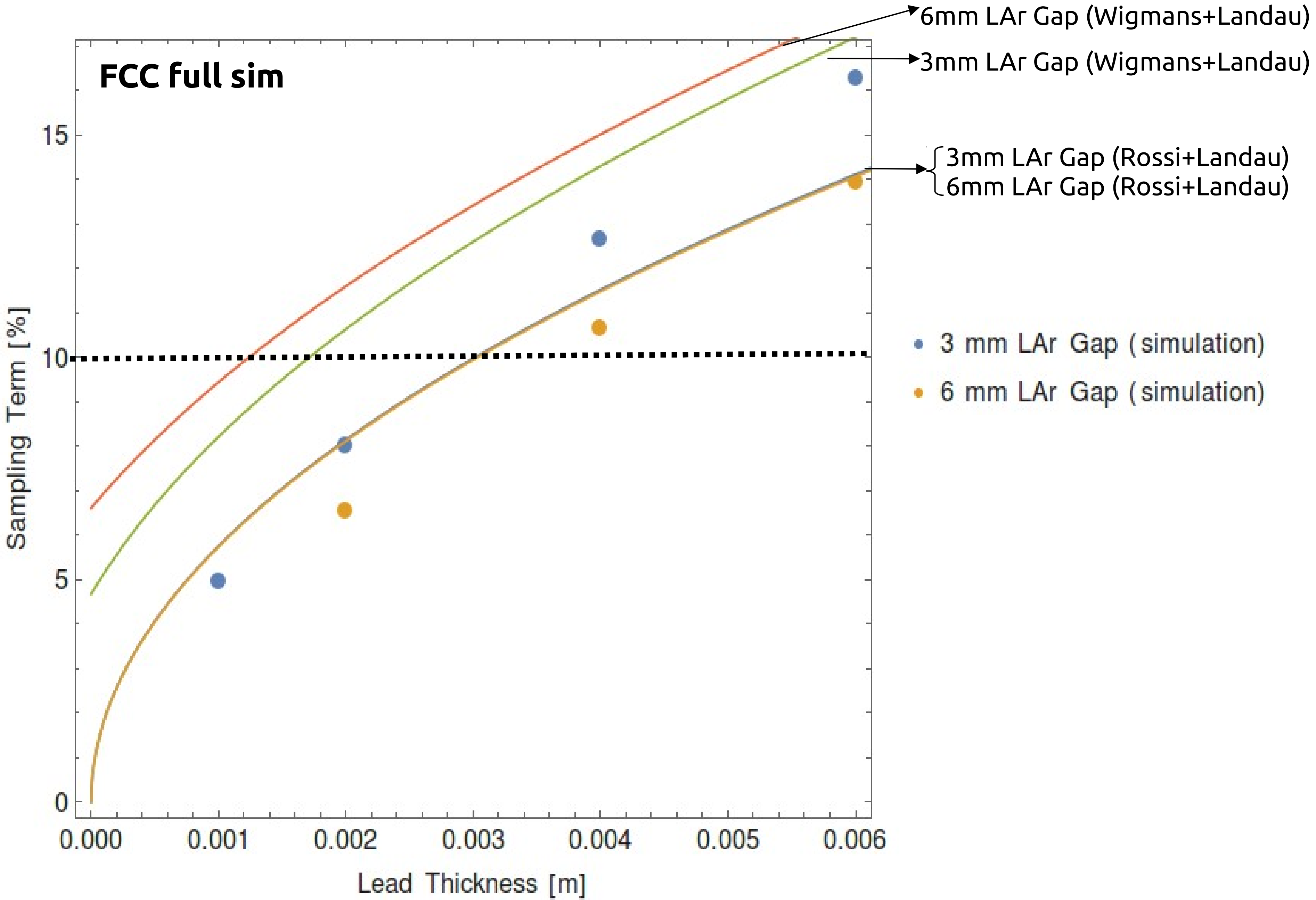
Amaldi, *Physica Scripta* 23 (1981), pp. 409-424

- Landau fluctuations: $a_{Landau} = 6.4\% \sqrt{\frac{E_C \cdot d_{abs}}{F \cdot X_0 \cdot \langle \cos\theta \rangle \cdot \log^2(k\delta)}}$
  - Deviations from Gaussian in thin layers

Amaldi, ibid.

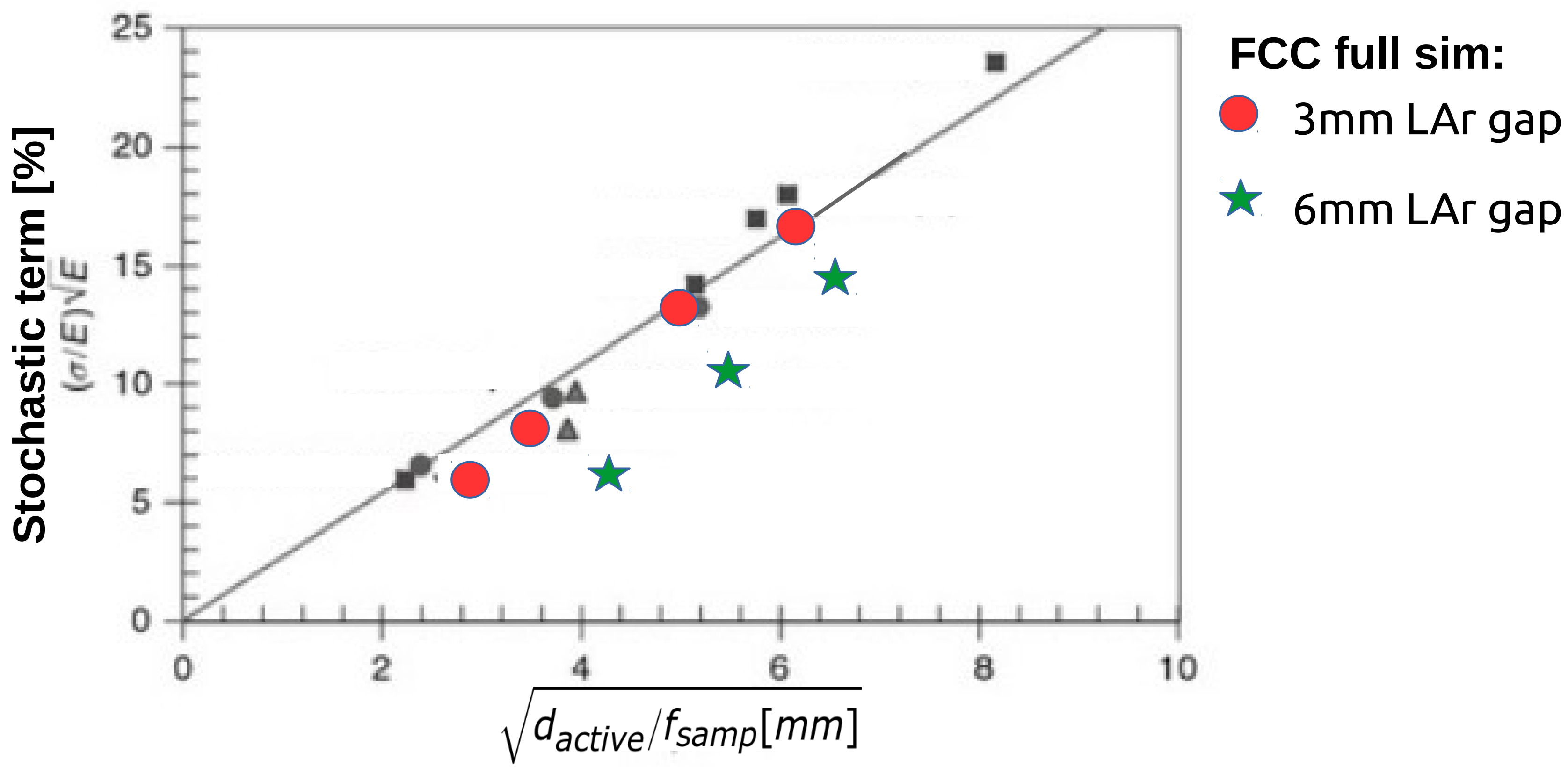
- Overall stochastic term is the quadratic sum: $a^2 = a^2_{samp} + a^2_{Landau} + \ldots$

Performance of (semi) empirical formulas



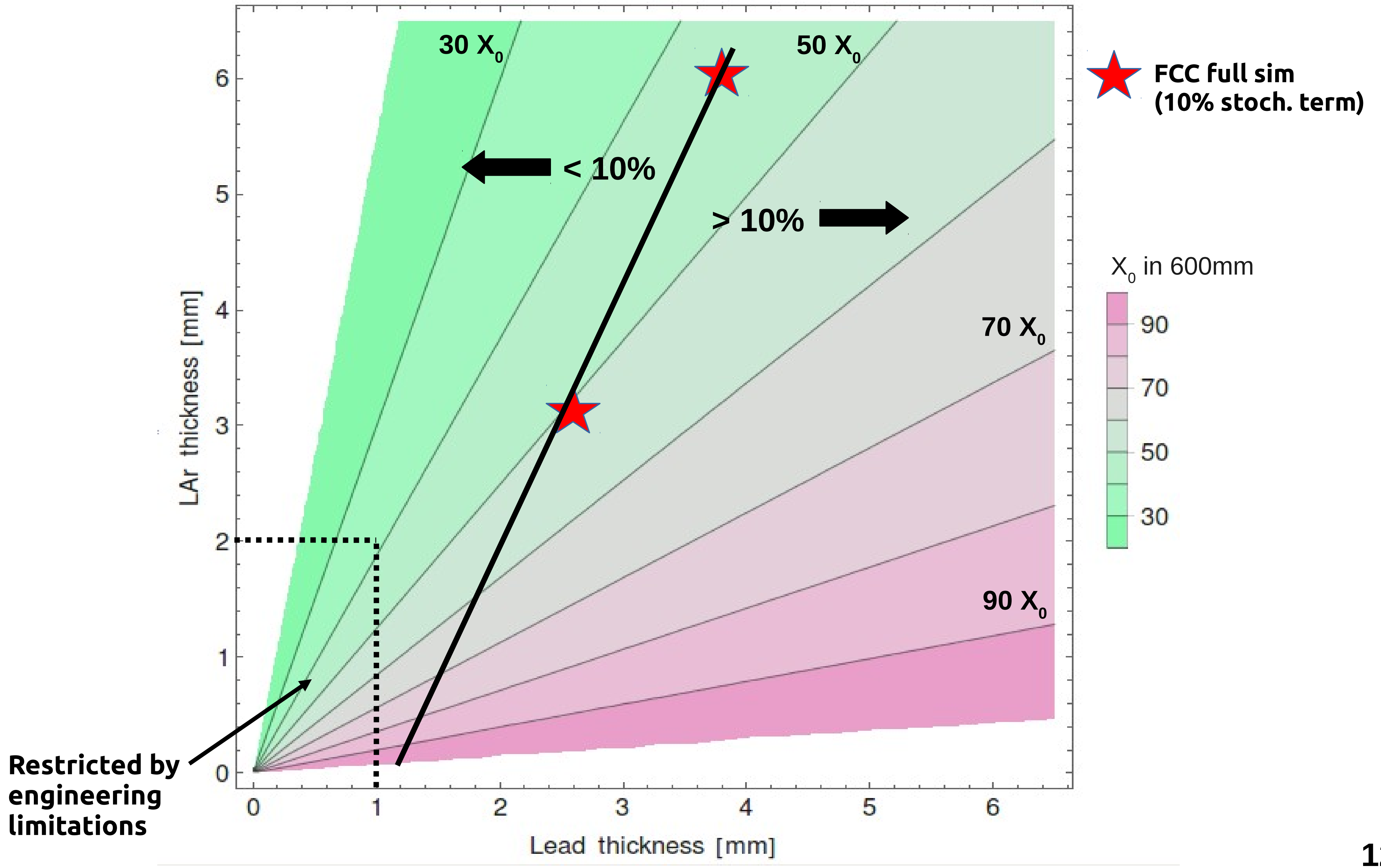
Comparison to real calorimeters

- Stochastic term is approximately linear in $\sqrt{d_{active}/f_{samp}[mm]}$
- Results obtained agree with Wigmans' parameterization for small LAr gap, within ± 2-3%
  - Wigmans ignores Landau fluctuations
  - Suitable only for *thin* active layers



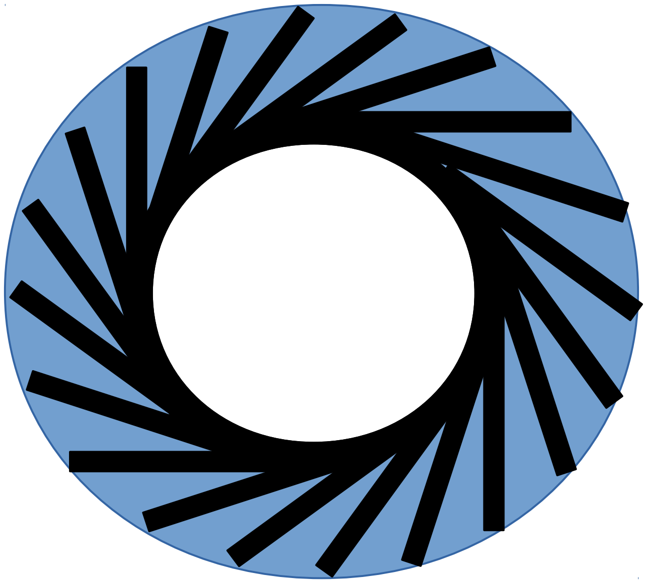
Plot from Wigmans, *Calorimetry: Energy Measurement in Particle Physics* (2000), Fig 4.8. (Quoted in Grupen.)

Preliminary ECAL design constraints



Conclusions & outlook

- Full FCCSW simulations of ECAL consistent with past sampling calorimeters
- Parameterizations for the stochastic term provide reasonable estimates
- Restricted parameter space for ECAL layer dimensions
- Future goals:
  - Effect of inner detector, cryostat, & *B*-field on resolution
  - Improved parameterizations
  - Absorber plate geometries
  - Clustering algorithm & noise



(sketch)