Template fit of the radial shower profile in LumiCal

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30th FCAL Workshop, 6-7 March 2017 CERN,

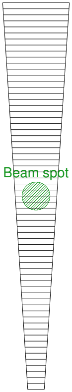
1. Introduction
2. Template fit – possibilities, challenges and limitations
3. Direct simulation of $\mathcal{R}_{90\%}$
4. Conclusions

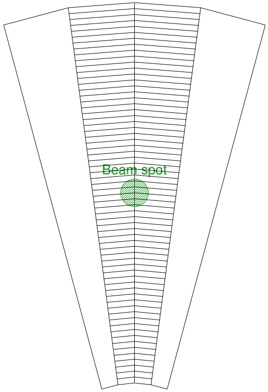
Section 1

Introduction

Precise measurement of transverse EM shower profiles

- With 1.8 mm pad height, LumiCal is perfectly suited for precise measurements of the transverse profile of EM showers.
- Assume that data from a prototype with 2+ full sectors of active pads becomes available soon.
- Analysis possibilities: Fit of the vertical profile or template fit.





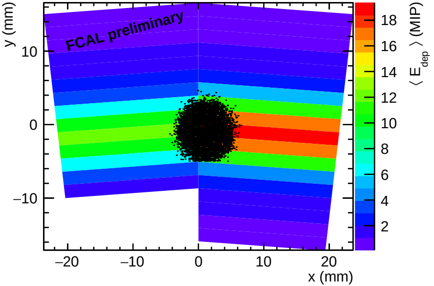
Section 2

Template fit – possibilities, challenges and limitations

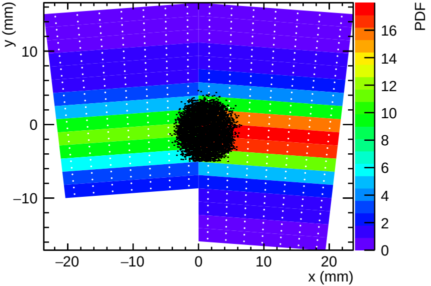
What is the template fit?

- Minimisation of χ^2 between the data and model histograms:
  - Data: measured or simulated deposits in the pads.
  - Model: Numerical integration of the parametrisation over the pads.
- Both the data and the model describe average energy as a function of the pad ID of the deposit and of the electron impact.

$$\left\langle E_{\text{dep}}(n_{\text{pad}}^{\text{deposit}}, n_{\text{pad}}^{\text{impact}}) \right\rangle$$

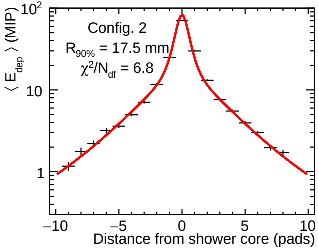


Average deposits – DD4hep sim (color)
Shower core cordinates (dots)



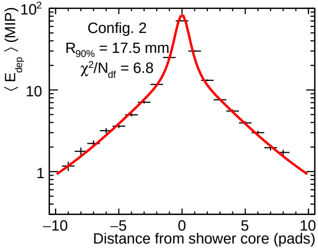
GP model, numerical integration (color)
Shower core cordinates (black dots)
Grid points (white dots)

Results (Beam spot in only one pad)



1D fit results

Results (Beam spot in only one pad)



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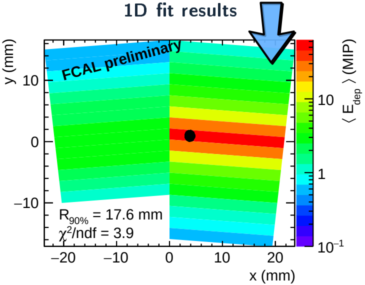
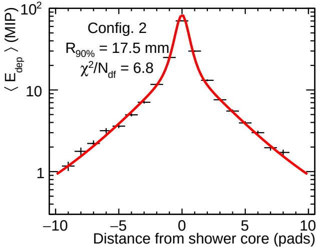


Template model with parameters from the 1D fit

Results (Beam spot in only one pad)



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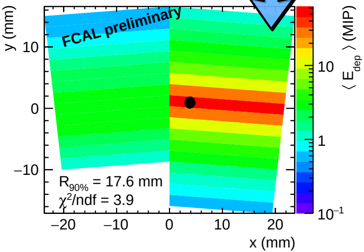
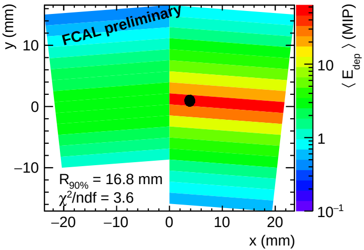
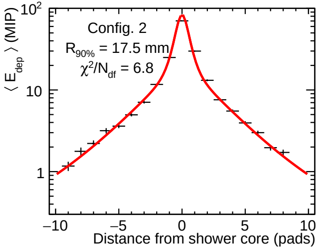


Template model with parameters from the 1D fit

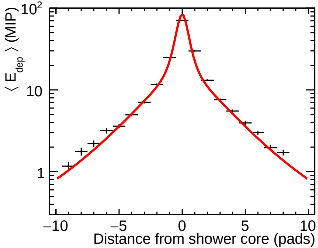


Template fit results

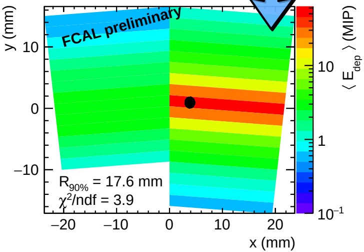
Results (Beam spot in only one pad)



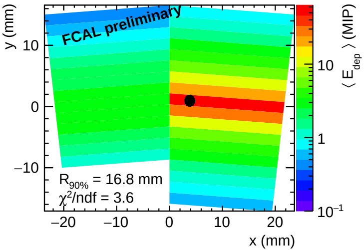
1D fit results



1D with parameters from the template fit



Template model with parameters from the 1D fit

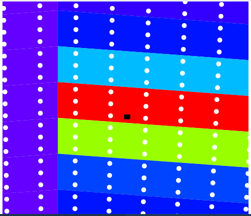


Template fit results

Challenges

Numerical integration of the model

- The grid currently used adapts to the pad shape, but not to the shape of the shower profile.
- Potential pitfalls: point-like beam hitting in-between the grid points (See below). Fortunately, this is not a realistic case.
- The universal solution would require advanced tesselation which takes into account both the pad structure and the profile shape and adapts to both for each beam electron.
- The present grid should work fine for beam spot sizes comparable or greater than the pad height (which is the realistic case).

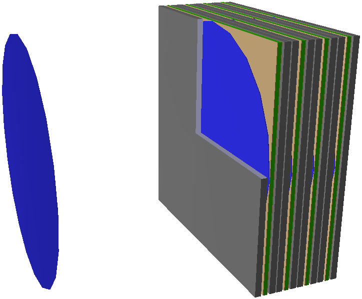


Section 3

Direct simulation of $\mathcal{R}_{90\%}$

Simulation of radial PDF – Geometry

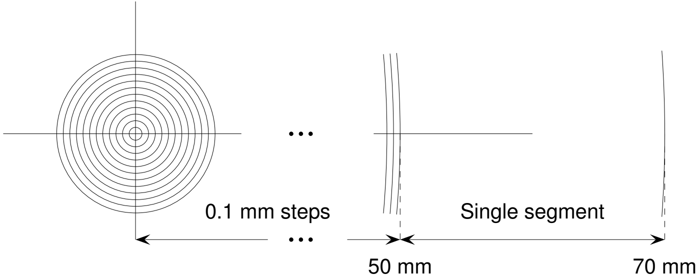
- Identical geometry as the LumiCal prototype
- Circular sensors with concentric radial segmentation
- Point-like beam hitting at the center of the sensor



Simulation of radial PDF – Segmentation

Segmentation adapted to extract radial PDF

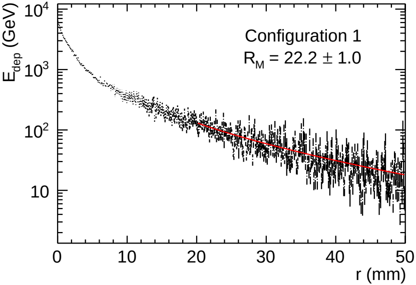
- Azimuthal division in 4 quadrants
- Radial steps of 0.1 mm from 0 to 50 mm. Single segment from 50 to 70 mm



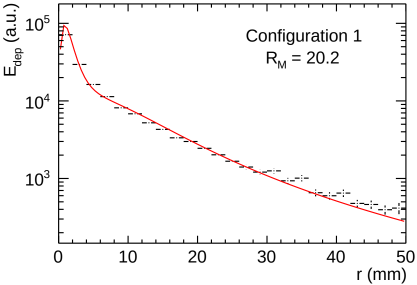
Simulation of radial PDF – Results

Two methods:

- Fit the tail to determine the fraction of energy leaking transversally; Find $\mathcal{R}_{90\%}$ directly from the histogram.
- Full fit of the radial PDF; Determine $\mathcal{R}_{90\%}$ from the fit parameters.



Fitted tail of the PDF



Full fit of the PDF

Simulation of radial PDF – Results

- Even when directly extracting $\mathcal{R}_{90\%}$ from the data and using fit only to determine the leaking fraction, results using different parametrisations differ by $\sim 20\%$.
- $\mathcal{R}_{90\%}$ is found in a relatively low region of the PDF with weak slope $\rightarrow$ very sensitive on the choice of parametrisation and the parameters.
- Existing parametrisations do not match simulated data well enough for a precise determination of $\mathcal{R}_{90\%}$. The situation with the data (when measured beyond $\sim 1 \times \mathcal{R}_{90\%}$) may or may not be different.

Results for $\mathcal{R}_{90\%}$ (mm)

Parametrisation	From histogram	From fit parameters
GP	22.2	20.2
GPmod	26.6	29.8

Conclusions

- Template fit in principle offers an accurate method of analysis of the transverse shower profiles.
- Existing parametrisations may not reproduce the data well enough.
- Model integration using a grid adapted to the pad shape is an approximate solution usable in realistic conditions. Advanced adaptive 2D tesselation would offer more robust integration.
- $\mathcal{R}_{90\%}$ is found in a relatively low and flat region of the transverse profile
  $\rightarrow$ extremely sensitive on the choice of parametrisation and the parameters.
- This method could be of interest for use with eventual future LumiCal prototypes with larger active area of the sensor. At the moment it is still unclear whether there is a crucial advantage over the simpler 1D fit procedure.