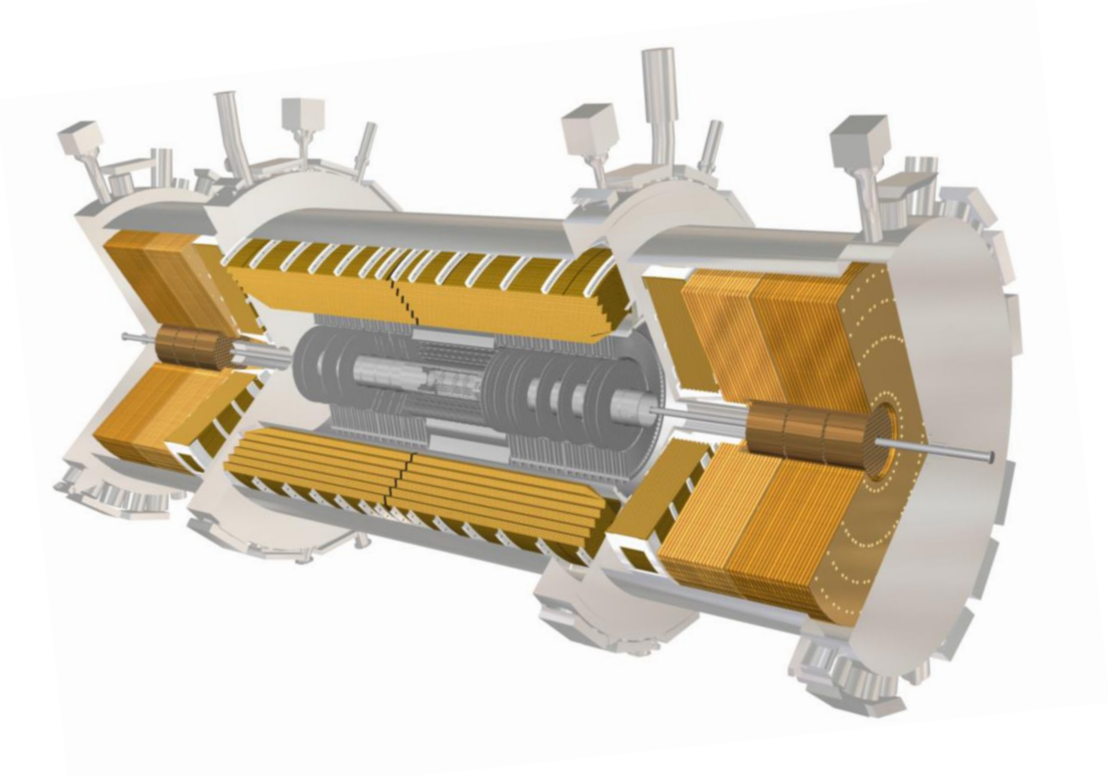
EM energy resolution studies with the ATLAS detector



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Summer Student Presentations 2022

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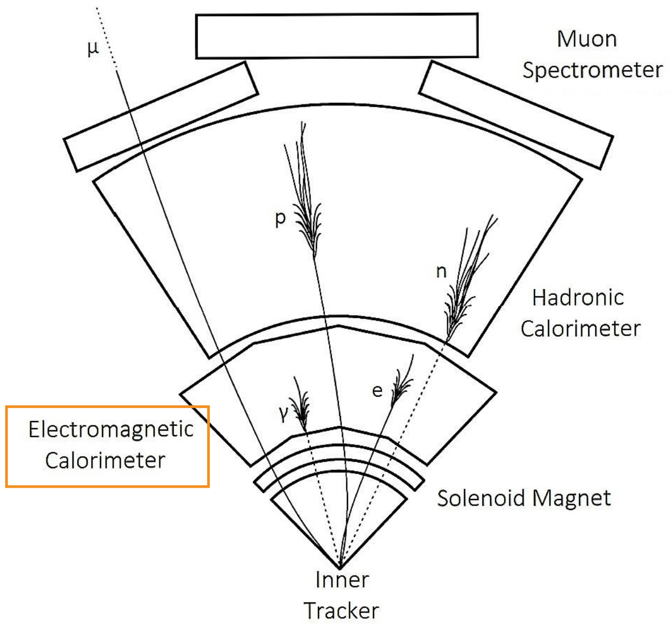
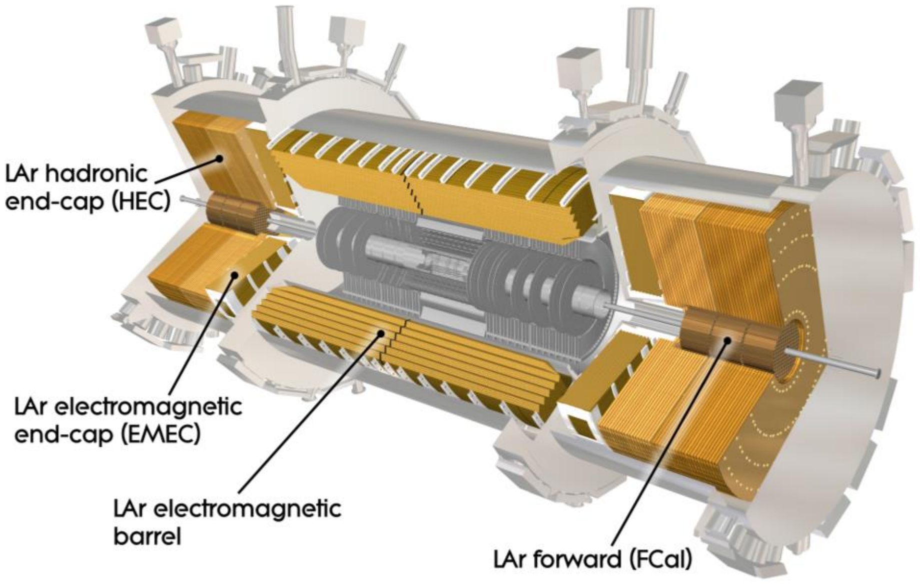
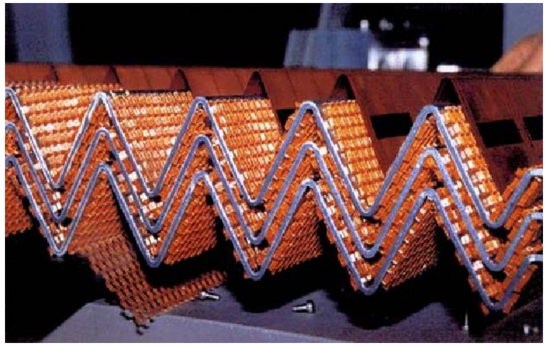
ATLAS Liquid Argon Calorimeter



- The energy of electrons and photons produced at ATLAS is measured by the Liquid Argon (LAr) calorimeter



- Found between the inner tracker and hadronic calorimeter



- It is a sampling calorimeter with accordion structure

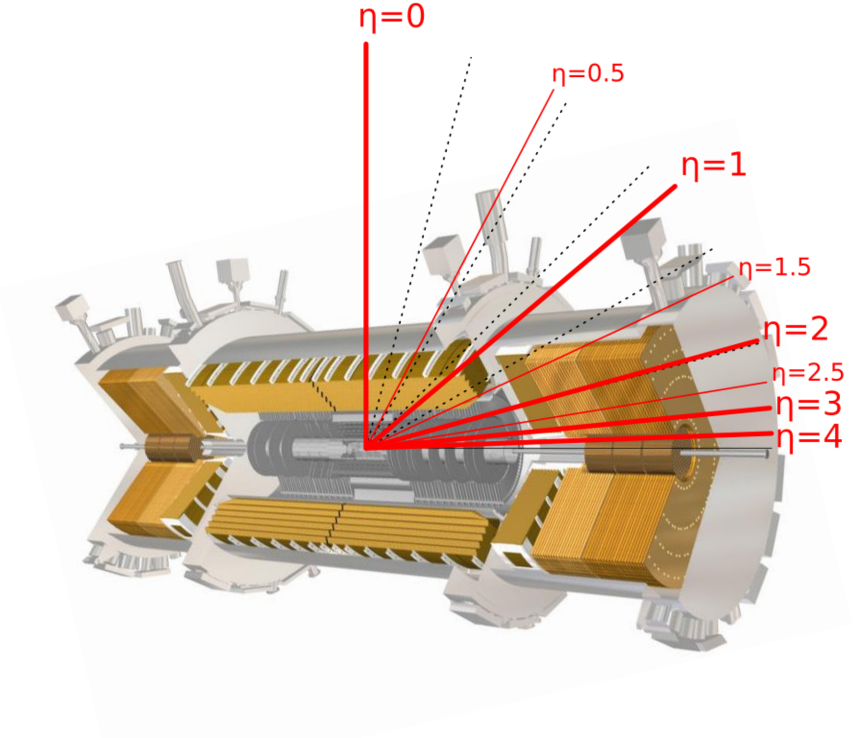
Relative energy resolution

- The relative energy resolution for electrons and photons is given by:

10%   250 MeV   0.7%

$$\frac{\sigma_E}{E} = \frac{a}{\sqrt{E}} \oplus \frac{b}{E} \oplus c$$

sampling term   noise term   constant term

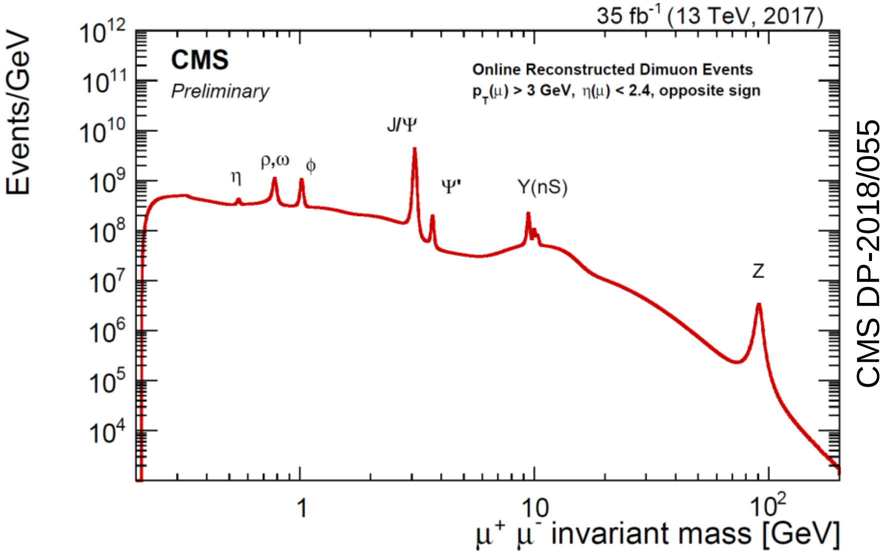


- *a* → due to the stochastic behaviour of shower evolution
- *b* → due to electronic and pile-up noise
- *c* → due to non-uniformities in the detector, radiation damage etc.

- The terms *a*, *b*, *c* depend on pseudorapidity η due to the amount of material encountered by the particle

$$\eta \equiv -\ln\left[\tan\left(\frac{\theta}{2}\right)\right]$$

Purpose of the project



- Usually, the total resolution is constrained at given η and mean electron energy ~ 40 GeV using the Z resonance width. This regime gives an effective constant term *c*, to be added in quadrature to the expected resolution

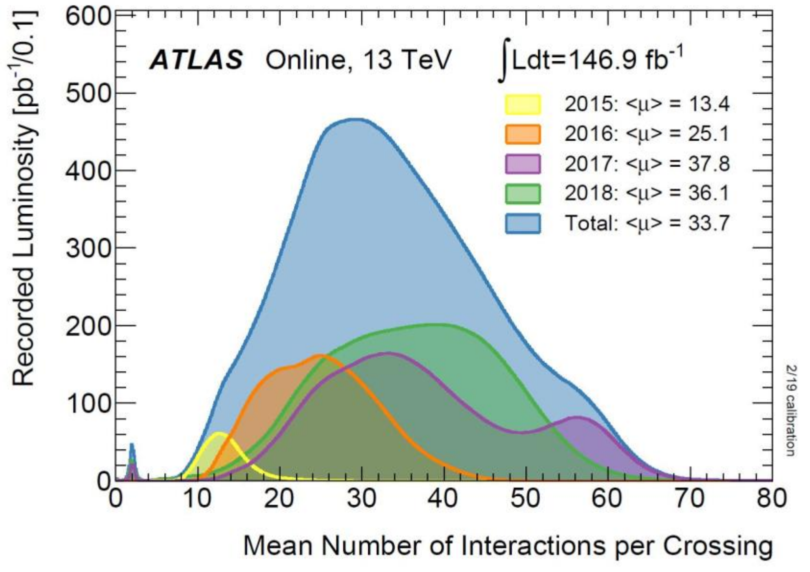
- The purpose of this project is to obtain an effective sampling term *a* by constraining the total resolution at given η and for average electron transverse energy of 11 GeV by studying the J/ψ resonance width

- The data used is 350 pb^{-1} of low pile-up data $\langle\mu\rangle=2$ collected by ATLAS at √s =13TeV. The very low pile-up and low energy regime will ensure that the *b* and *c* terms are respectively subdominant

- Improved knowledge on the sampling term using low pile-up data would improve the modelling of the response of the ATLAS LAr calorimeter

"Yesterday's signal is today's background and tomorrow's calibration"

A. Geiser from the lecture series



Determination of energy scale and resolution

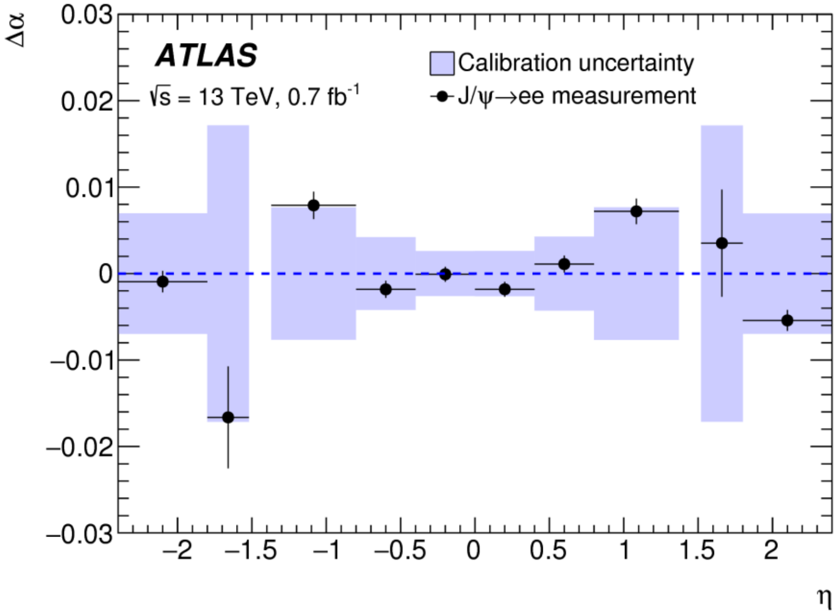
- The dielectron invariant mass distribution at J/ψ mass is used for both calibration and the determination of energy resolution corrections. The analysis is carried for electron pairs grouped by η regions, labelled (i, j) using the following binning [0.0,0.4,0.8,1.37-1.52,2.47]

- Comparing the reconstructed J/ψ peak position in data and the Monte Carlo (MC) simulation allows for the determination of the energy scale correction. Starting from the energy scale definition $E_{Data} = E_{MC}(1+\alpha)$ and propagating through the invariant mass formula, one gets:

$$m_{ee}^{Data} = m_{ee}^{MC}\left(1 + \frac{\alpha_i + \alpha_j}{2}\right)$$

- After the scale correction is determined, a similar comparison of the reconstructed J/ψ peak width gives the resolution correction

$$\sigma_{m_{ee}^{Data}} = \left(1 + \frac{\alpha_i + \alpha_j}{2}\right)\sqrt{\sigma^2_{m_{ee}^{MC}} + \frac{{m_{ee}}^2 MC}{4}\left(\frac{\Delta a_i^2}{\langle E_i\rangle} + \frac{\Delta a_j^2}{\langle E_j\rangle}\right)}$$



- The terms α and Δ*a* are extracted and are expected to be centered around 0

Preparing the data

- Electron pairs can be distinguished as originating in prompt or non-prompt J/ψ. Since non-prompt J/ψ are from secondary decays as opposed to being produced at the interaction point, they have larger pseudopropertime τ

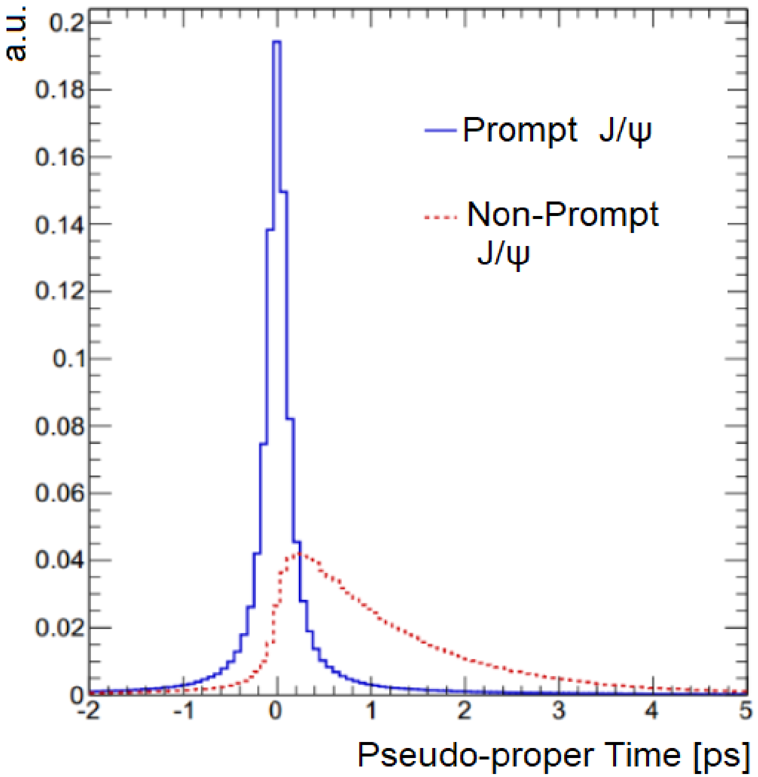
Decay length in the transverse plane

$$\tau = \frac{L_{xy} m^{J/\psi}}{p_T^{J/\psi}}$$

- The data has been filtered for electrons of same charge sign to remove background due to misidentified electrons

- Pre-selection: electron cuts: p_T>4.5 GeV, Crack cut, |η|<2.47, MediumID

- Dielectron cuts: 2 electrons, p_T>5, 4.5 GeV, 2.1<m_{ee}<4.1 GeV



Monte Carlo simulation of τ distribution

Fitting data

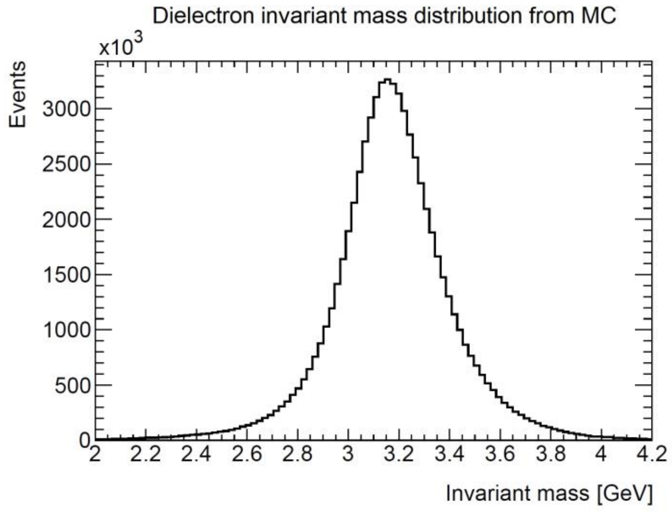
- The signal + background PDF contains:

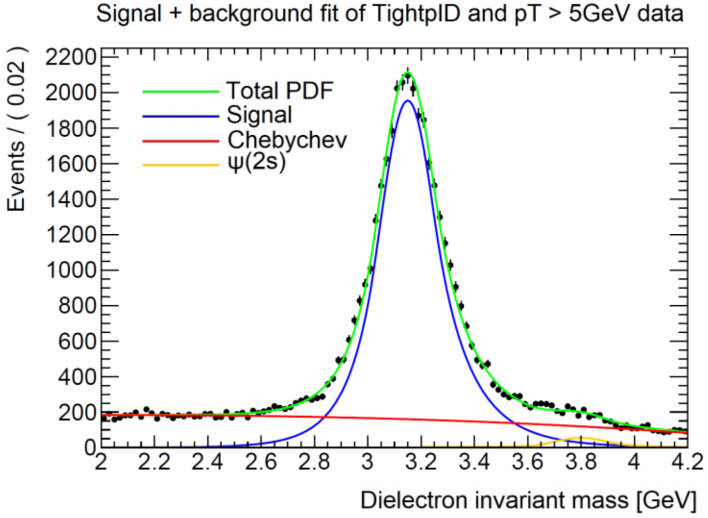
Double Sided Crystal Ball function for signal

$\boxed{\text{DSCB}(J/\psi)} + \boxed{\text{DSCB}(\psi 2S) + \text{ChebPol (3)}}$

$\Psi(2S)$ resonance + 3rd order Chebychev polynomial for continuous irreducible Drell-Yan background

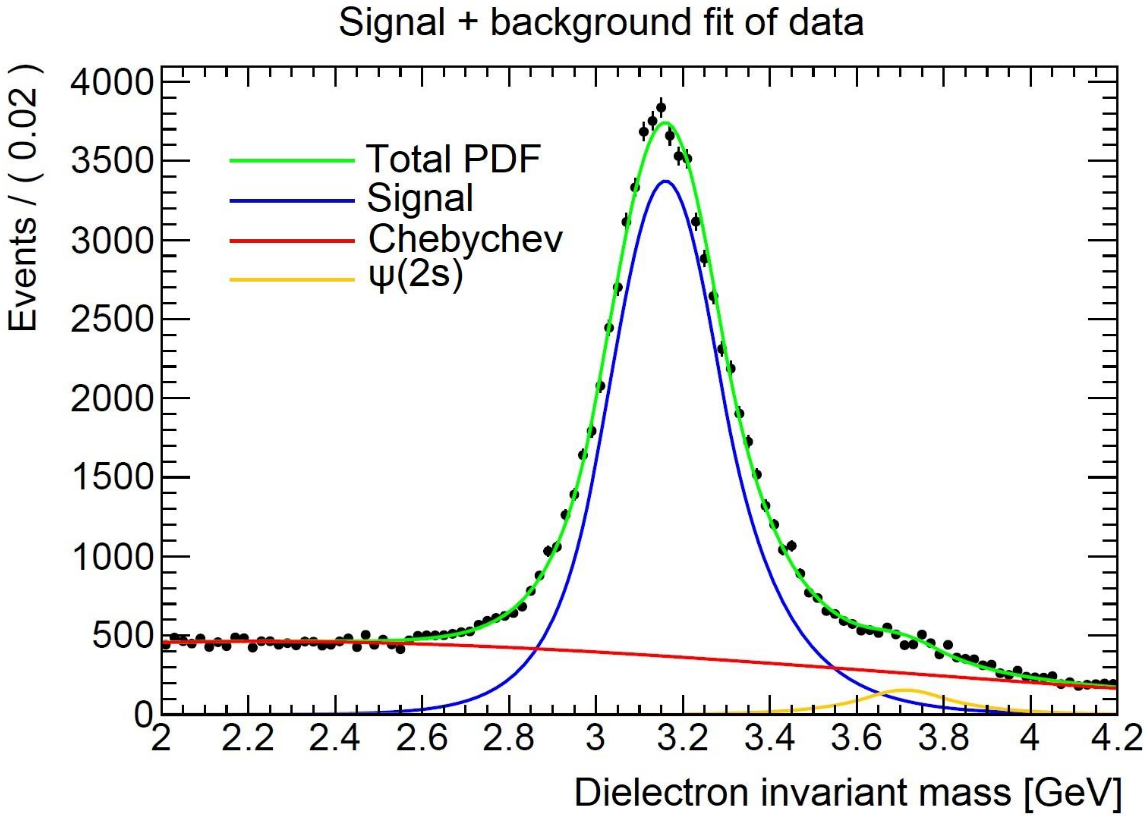
- Normally the signal alone would be fitted from MC first to ease the estimation of the background, however there were delays in the production of MC beyond our control, so a temporary solution was found





- To "fake" the MC, an initial fit of the signal was performed on data filtered for TightpID and p_T>5GeV, to reduce the background contribution
- The resulting signal PDF was then applied to the full data and allowed for improved estimation of the background

Results

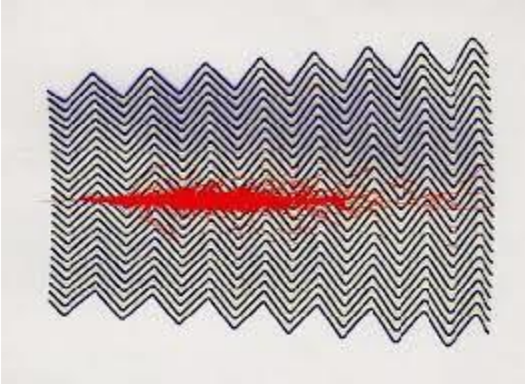


reduced χ^2= 1.68

- Good fit quality with reduced χ^2= 1.68, considering there are no constraints from MC
- The Chebychev shape was difficult to obtain, because without a good constraint of the signal, the DSCB overestimates the tails, highlighting the importance of the initial MC fit
- The $\psi(2S)$ peak is also difficult to model without MC, since the signal and background peaks are so close

Conclusion

- EM resolution study of the LAr calorimeter at ATLAS
- The project's aim is to access the relative energy resolution sampling term *a* using low pile-up, low energy data
- Comparisons between the J/ψ mass peak position and width between data and MC give the energy scale and resolution corrections per η bin
- Next, a simultaneous fit will be performed on data and MC samples per η bin and the analysis will be extended to include non-prompt J/ψ



- In result, the improved modelling of the response of the ATLAS LAr calorimeter in different energy and η regimes is useful to the various measurements and searches carried with the ATLAS detector