SCUOLA NORMALE SUPERIORE

Rapidity and helicity distributions of *W* bosons at the LHC

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EW precision measurements workshop

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based on

arXiv:1707.09344

About the rapidity and helicity distributions of the W bosons produced at LHC

E.M., O.Cerri, N.Foppiani, G.Rolandi

The “PDFs uncertainty” is currently one of the dominant systematics in the *W* mass measurement

So far two possible approaches to reduce this uncertainty:

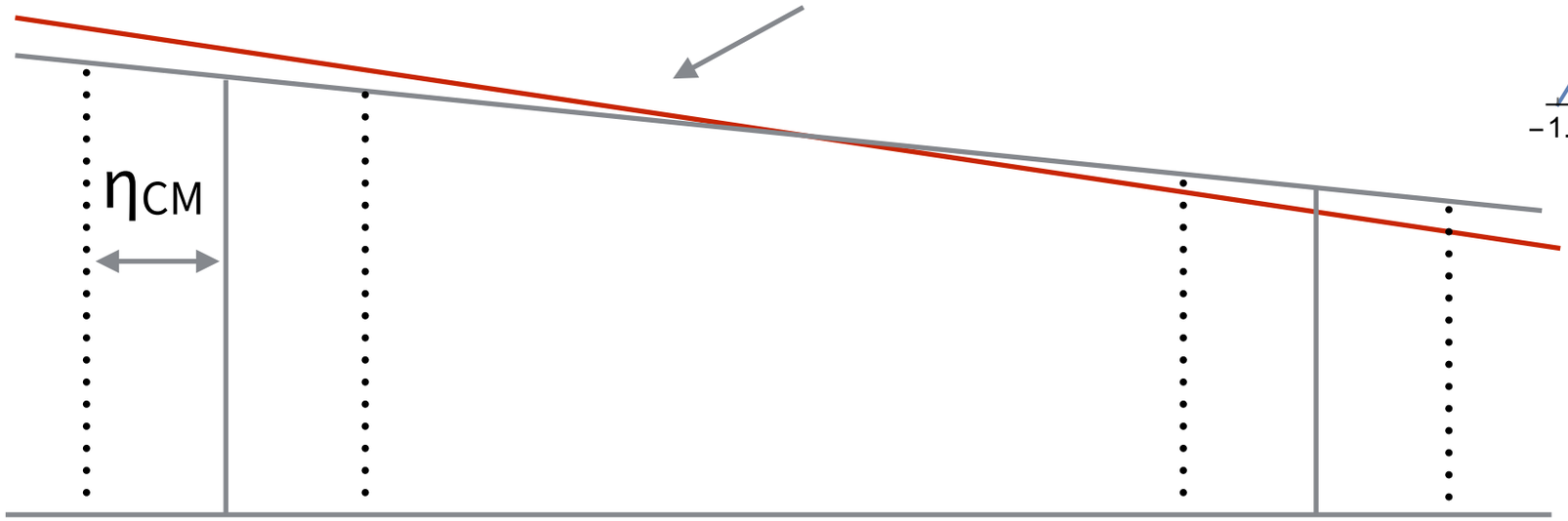
- Refine the PDFs fit adding measurements sensitive to PDFs as a constraint (*Z* rapidity and p_T, *W* charge asymmetry….)
- Devise new fit procedures that smartly reduce the uncertainty (binning in eta, fitting W+ and W- simultaneously, PDFs profiling…)

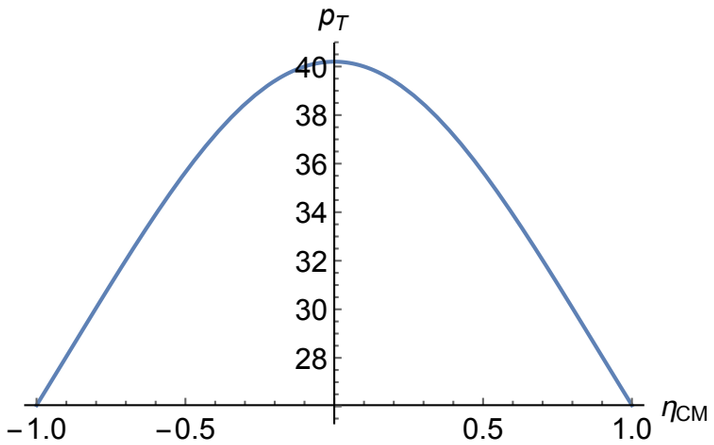
where does “PDF uncertainty” come from?

boost to lab frame:

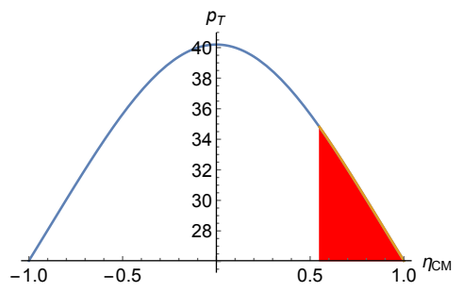
$\eta_{LAB} = \eta_{CM} + Y$

uncertainty on
Y shape due to PDFs

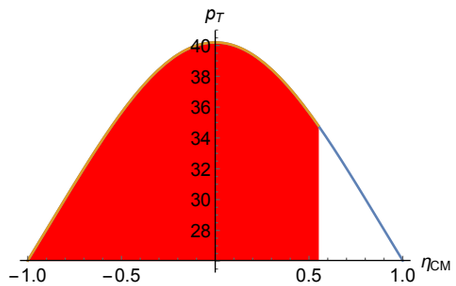




neglecting *W* p_T



+



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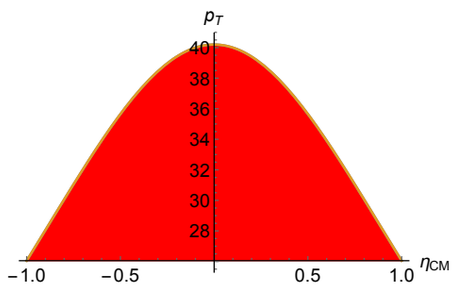
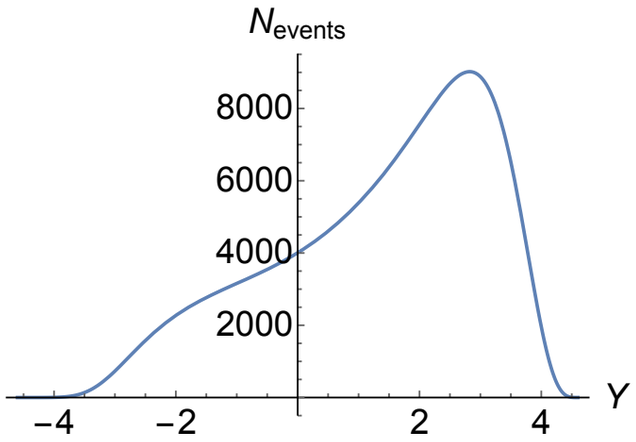
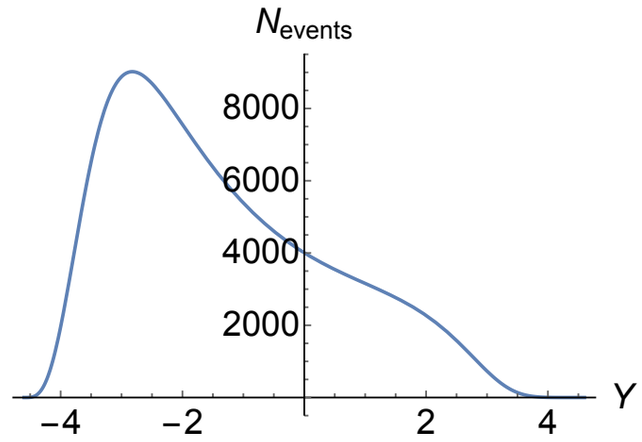


in addition, *W* polarisation…





u

d-bar

direction in z axis

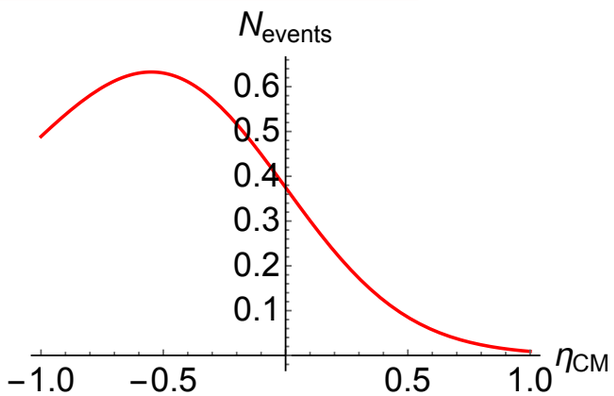
d-bar

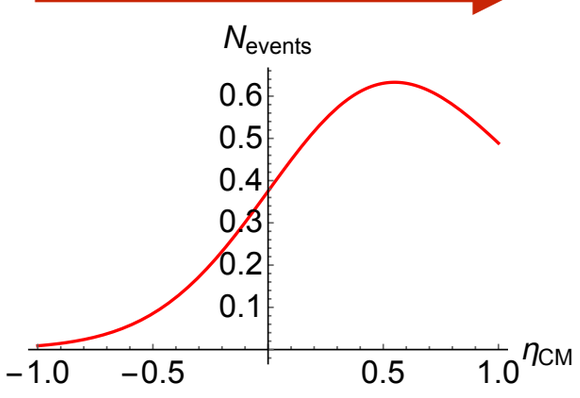
u

spin

spin of W

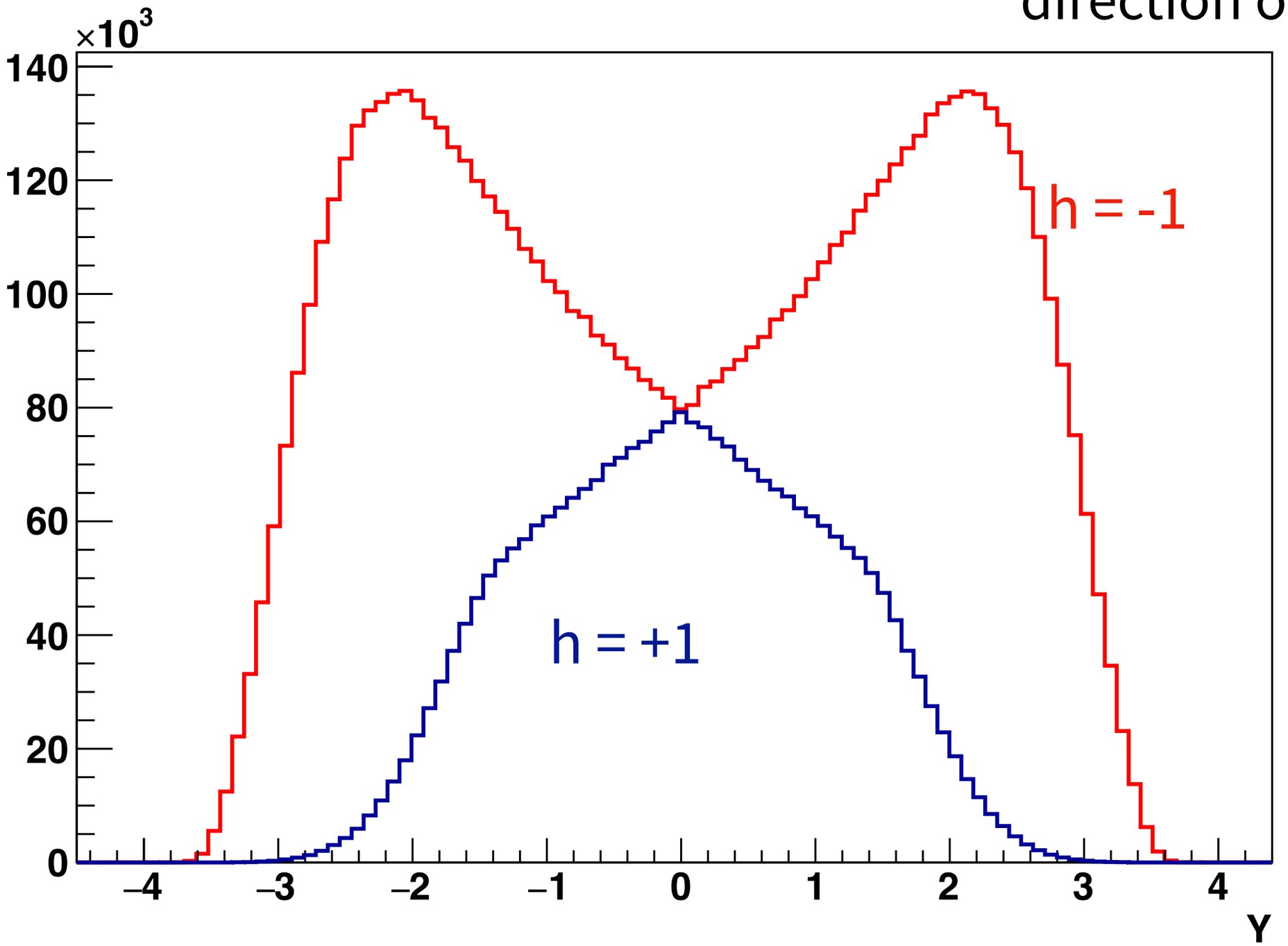
preferential direction of μ^+



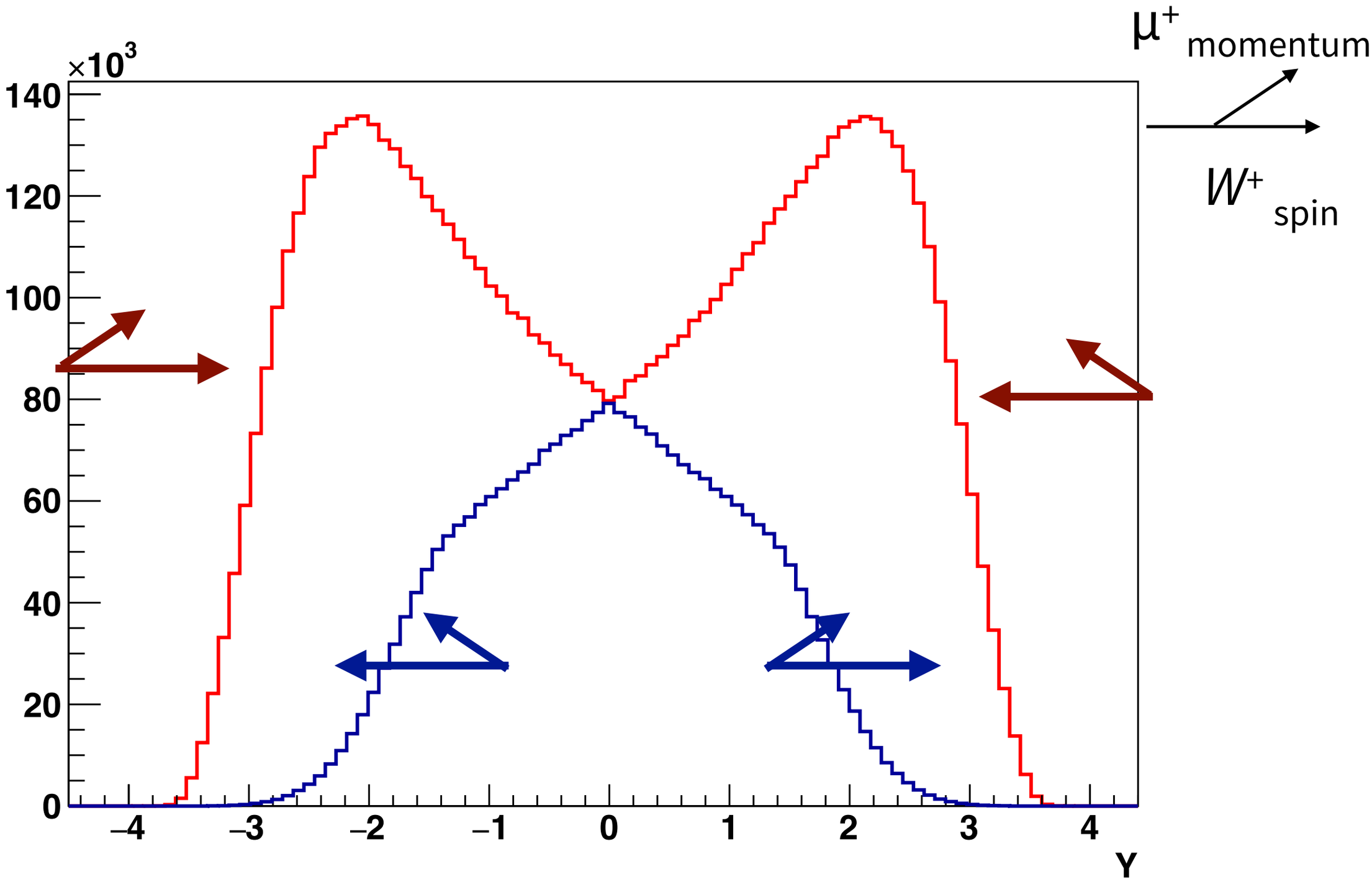


… now look at it in this way

helicity = spin component along direction of motion



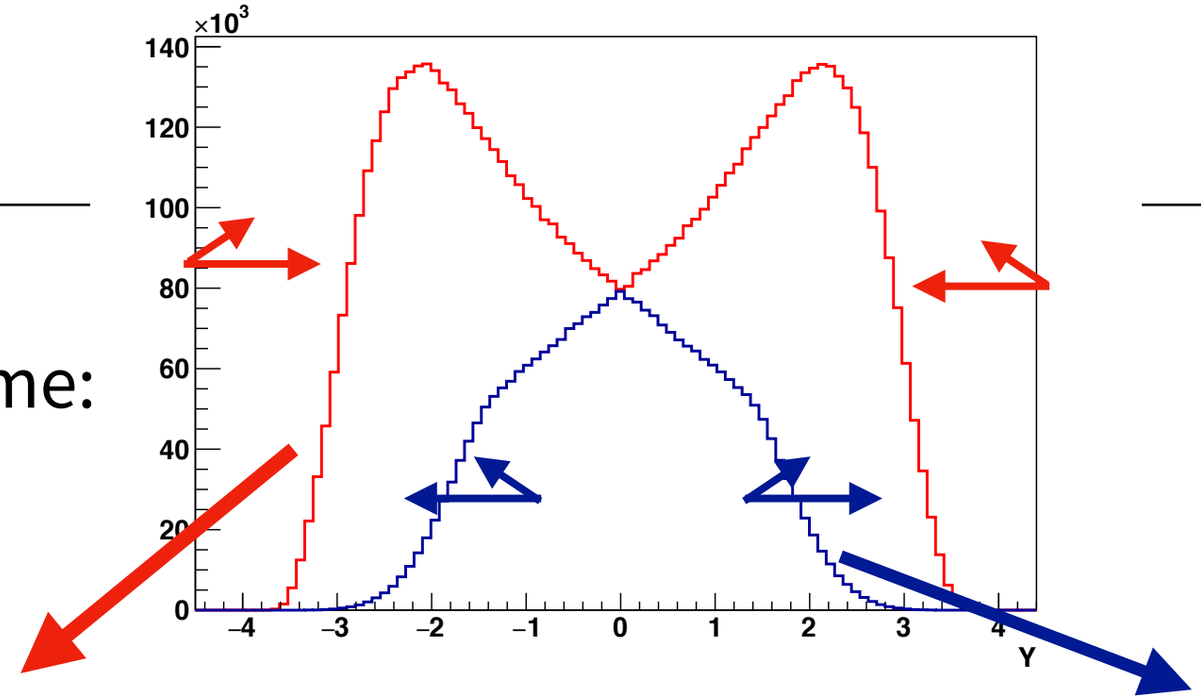
the *W* decay has a strong spin analysing power



boost to lab frame:

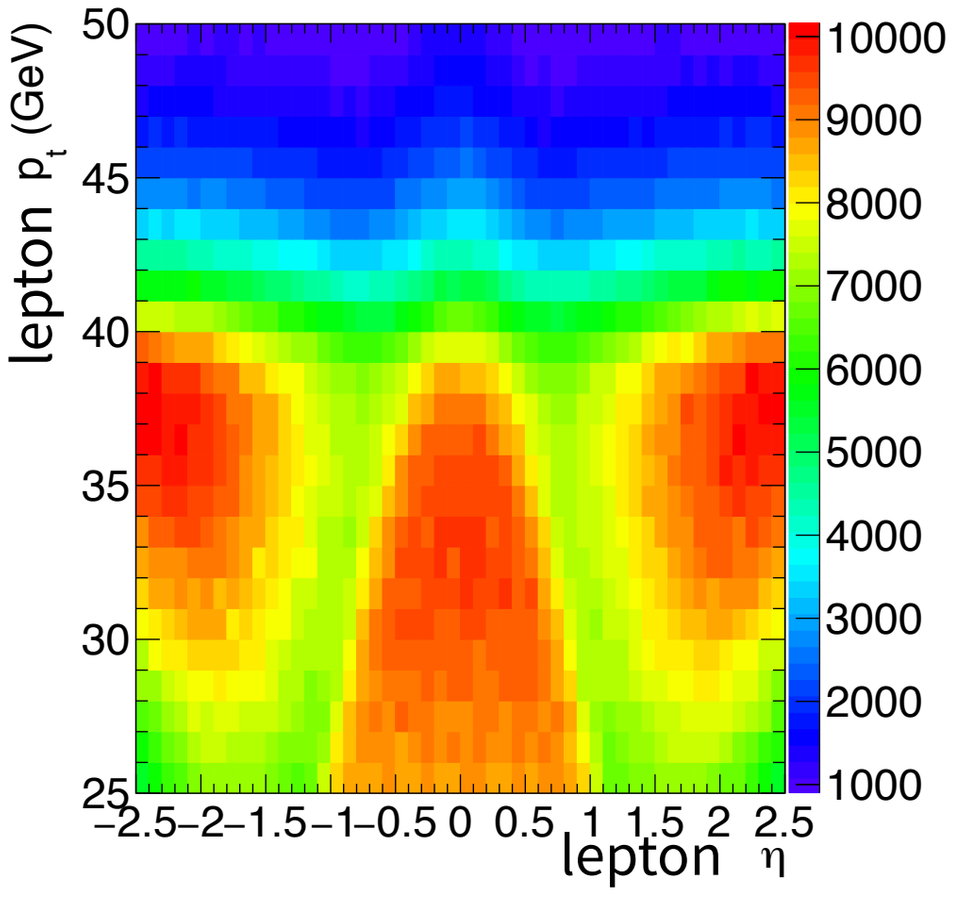
$\eta_{LAB} = \eta_{CM} + Y$

$\eta_{cm} \sim \pm 0.5$

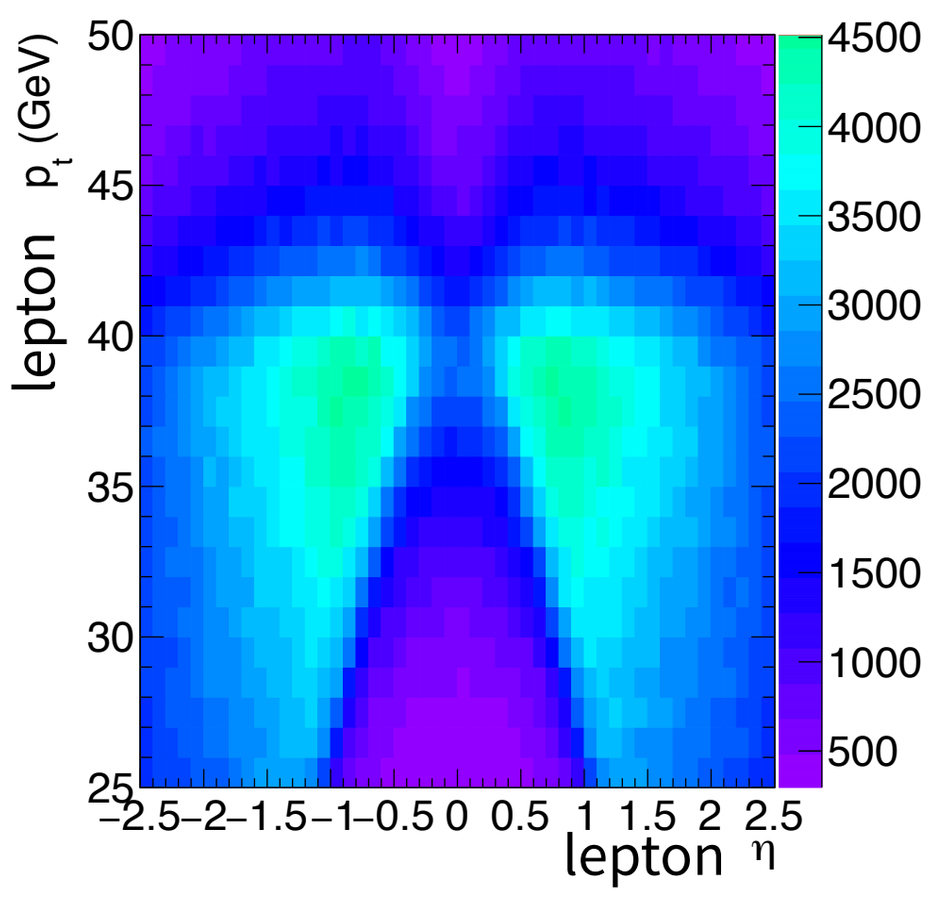


μ^+ momentum

W^+ spin



h<0



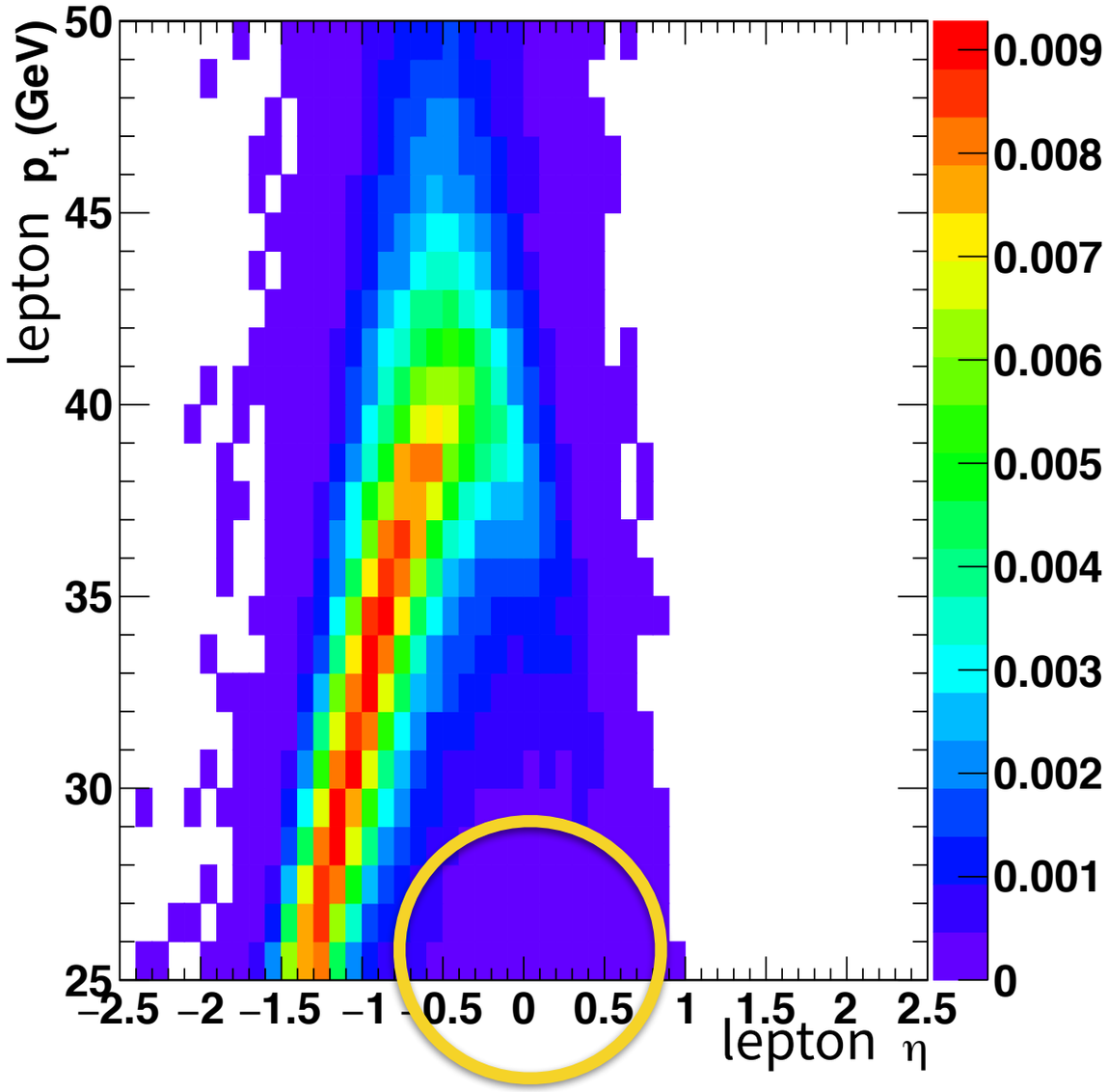
h>0

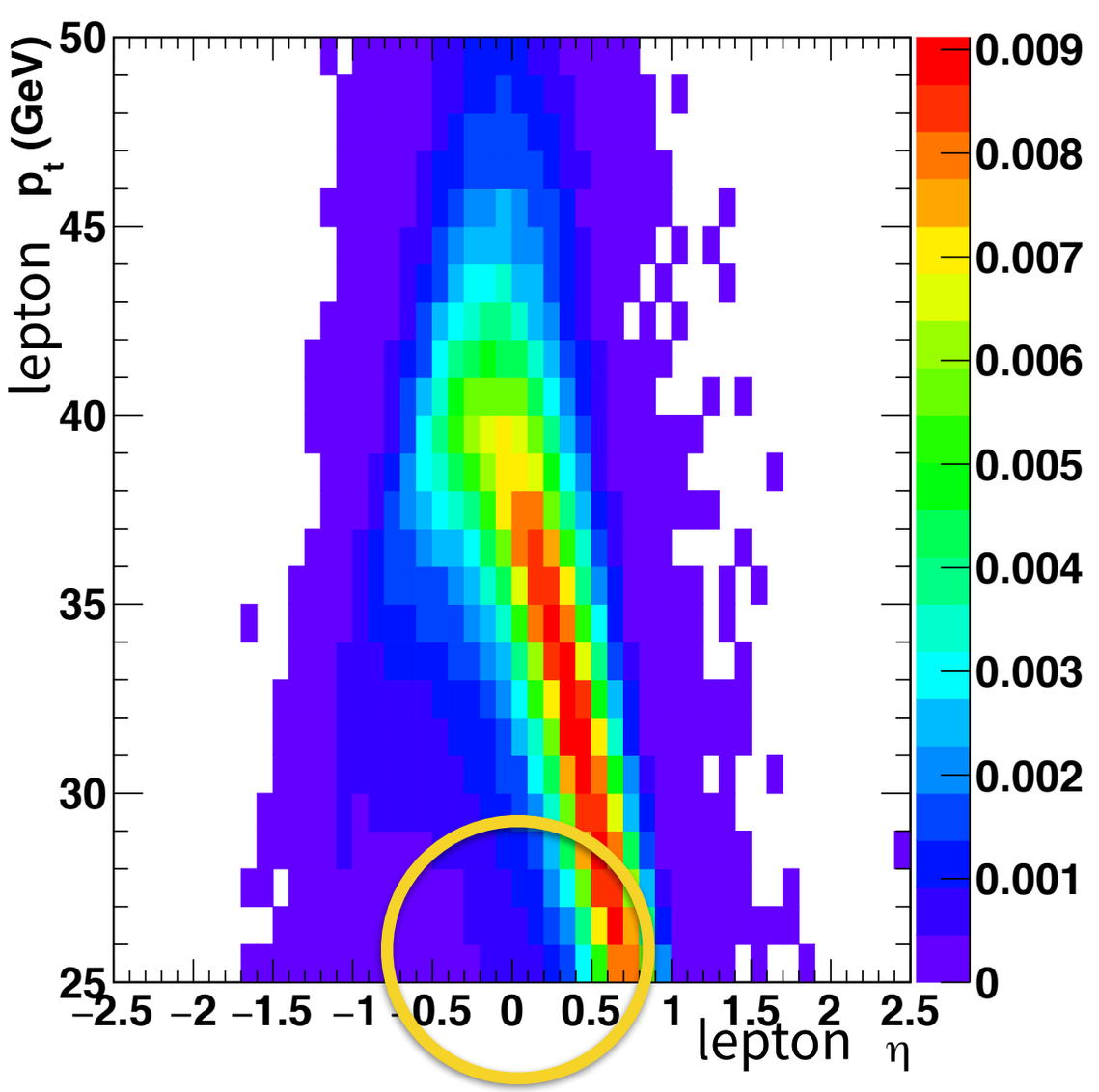
this observation opens the possibility of measuring the *W* rapidity spectrum for each helicity

we tried to do this exercise with a sample generated with Pythia8, with NNPDF2.3 QCD+QED LO

we performed an analytic chi2 fit using 2*23 templates
(2 helicities * 23 bin in rapidity)
1 GeV bins in p_T (25 to 50 GeV) and 50 bins in η_{LAB}

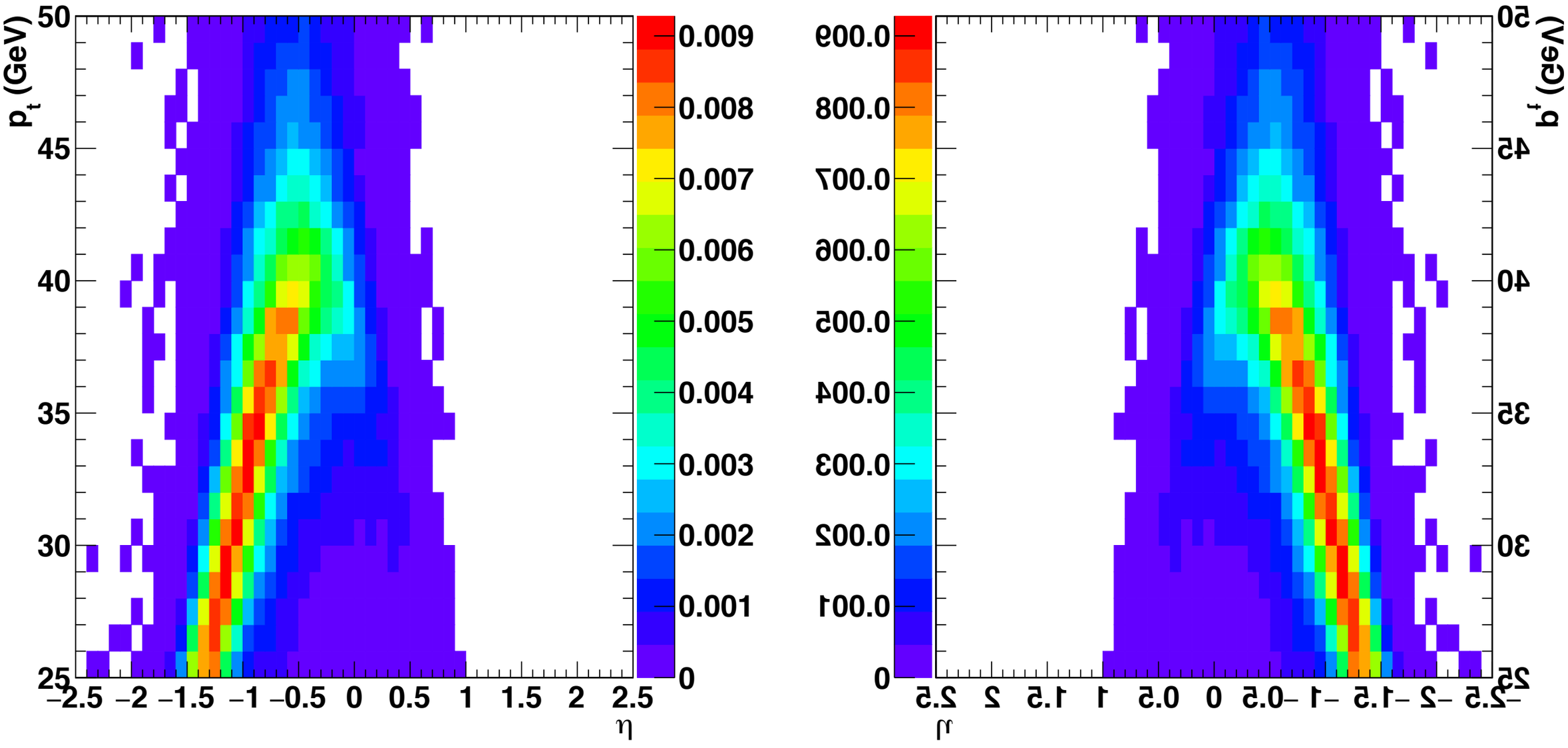
same rapidity, opposite helicity





for a given helicity, templates at opposite rapidities are mirror image of themselves

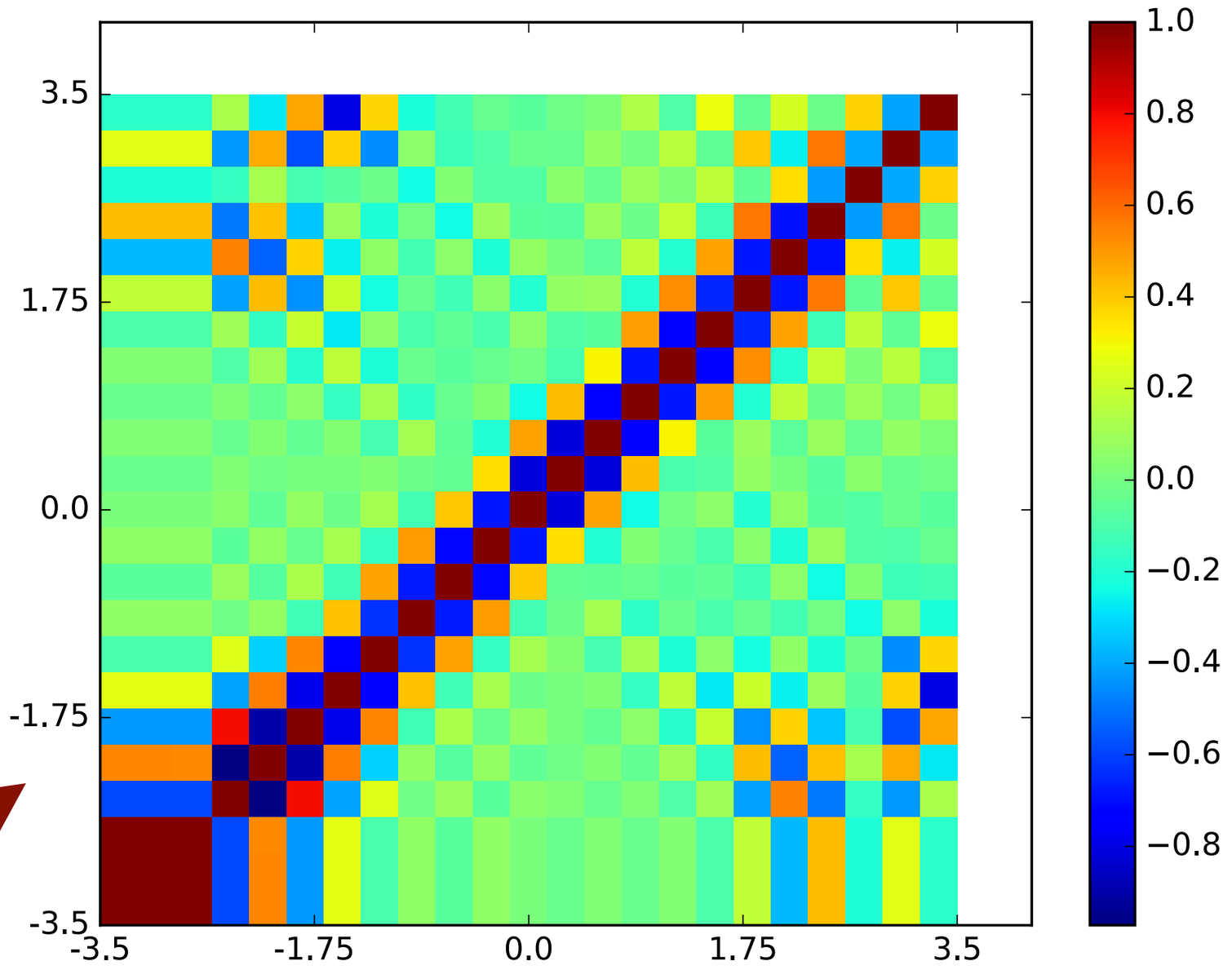
opposite rapidity, same helicity



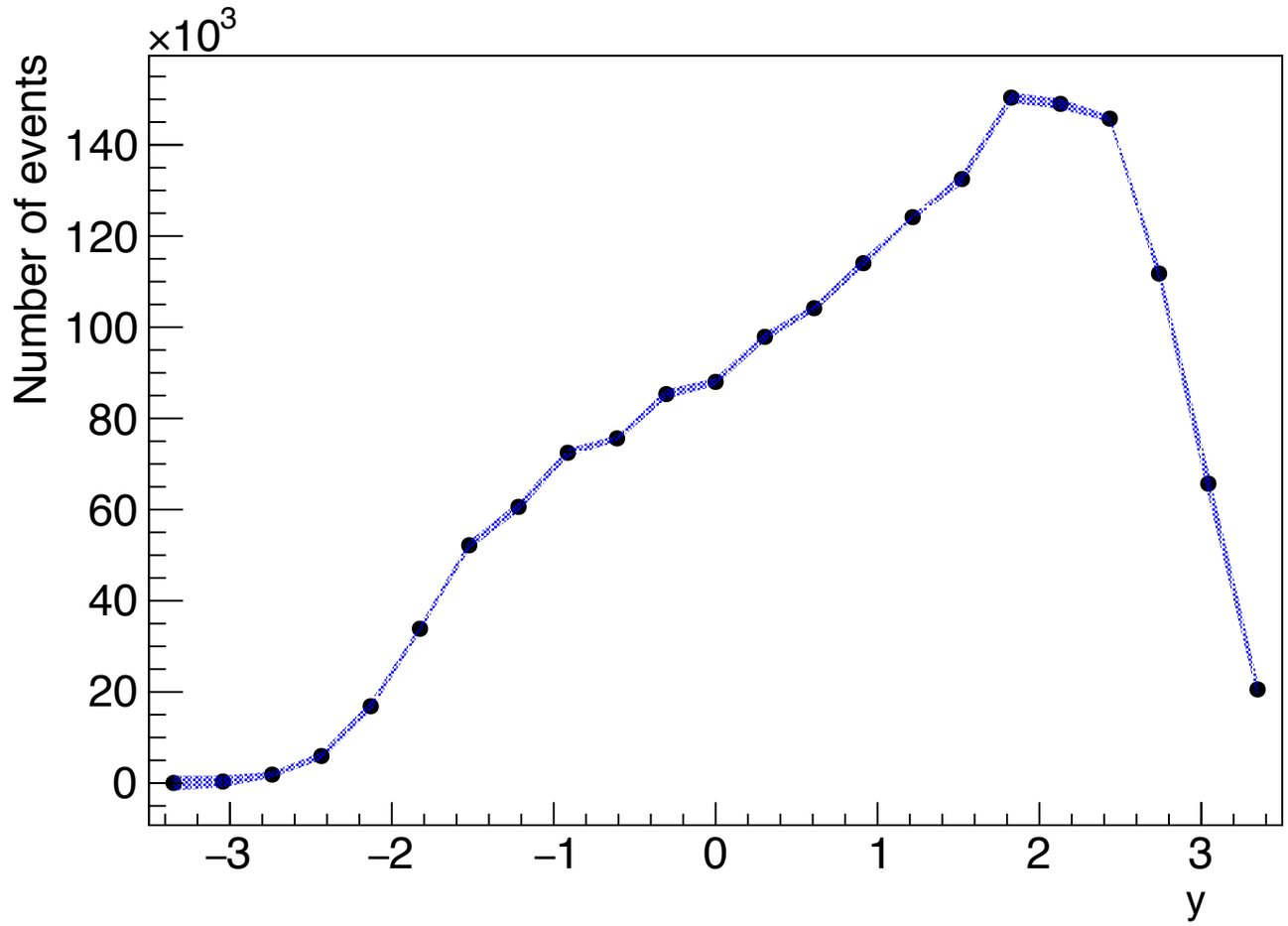
correlation matrix of the fit

at large rapidities there is less constraint

each bin is strongly anti correlated with its neighbour



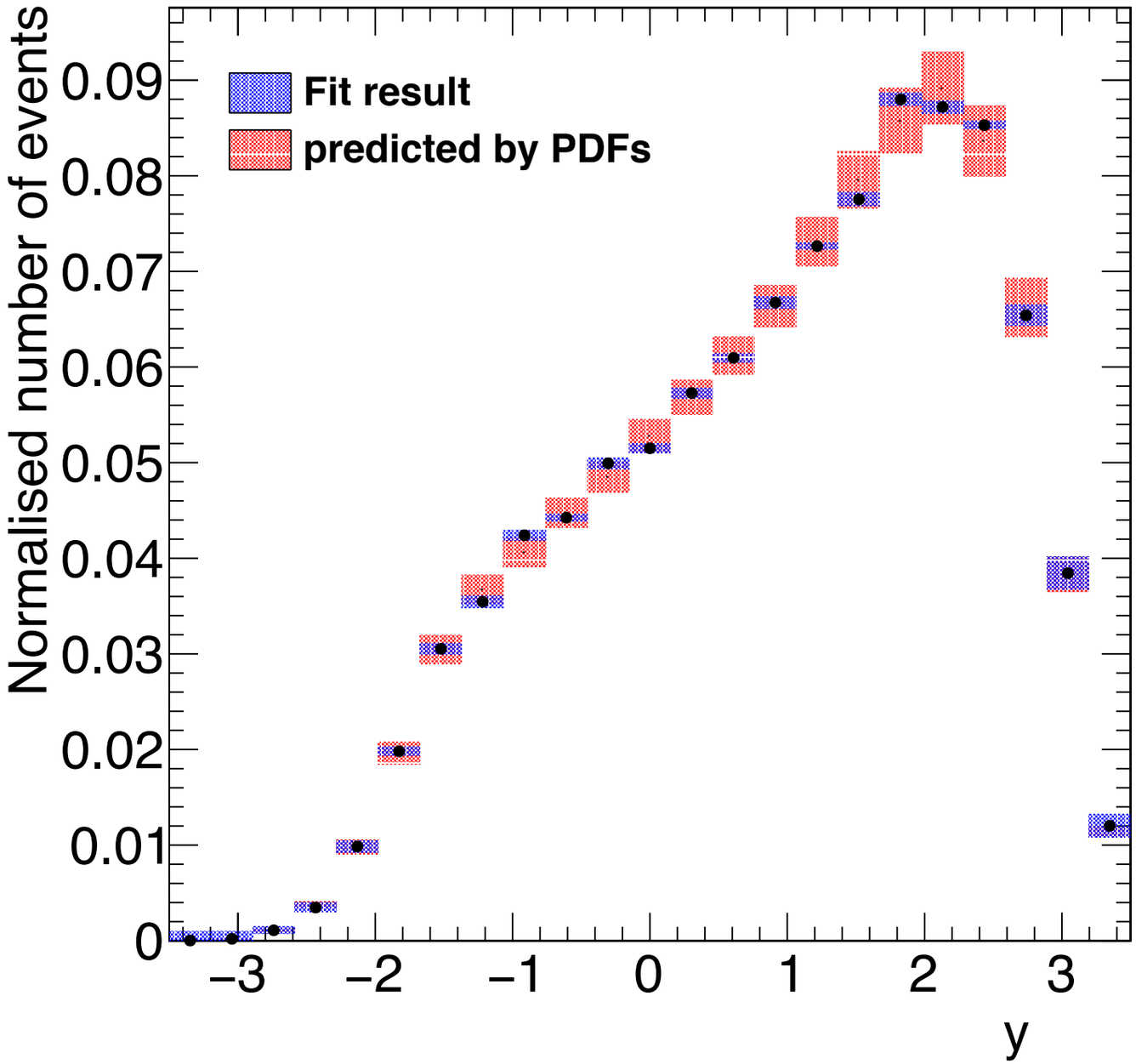
fit result

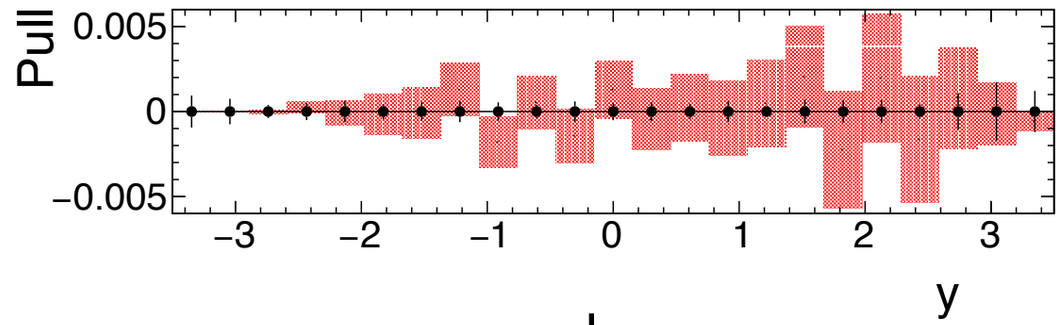


~ 1 M events used for the pseudo data
reduced chi2 of the fit very close to 1

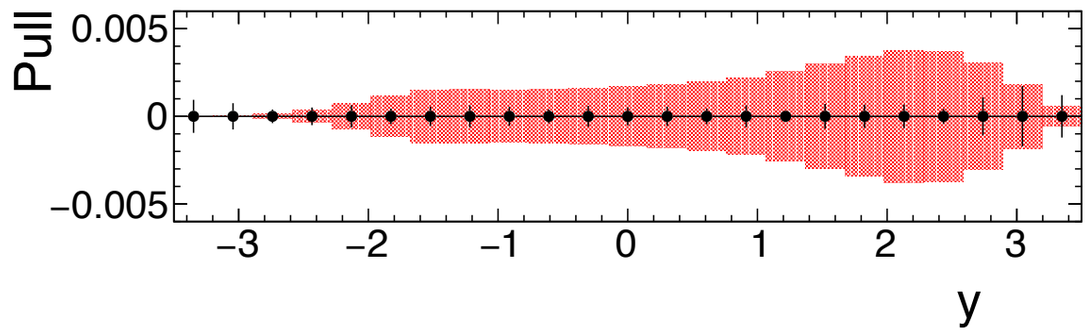
error bars show the result of the full propagation of the correlation via diagonalisation of the covariance matrix

comparison with PDFs prediction





equalise central values



~ 1σ compatibility data/truth

systematic uncertainties

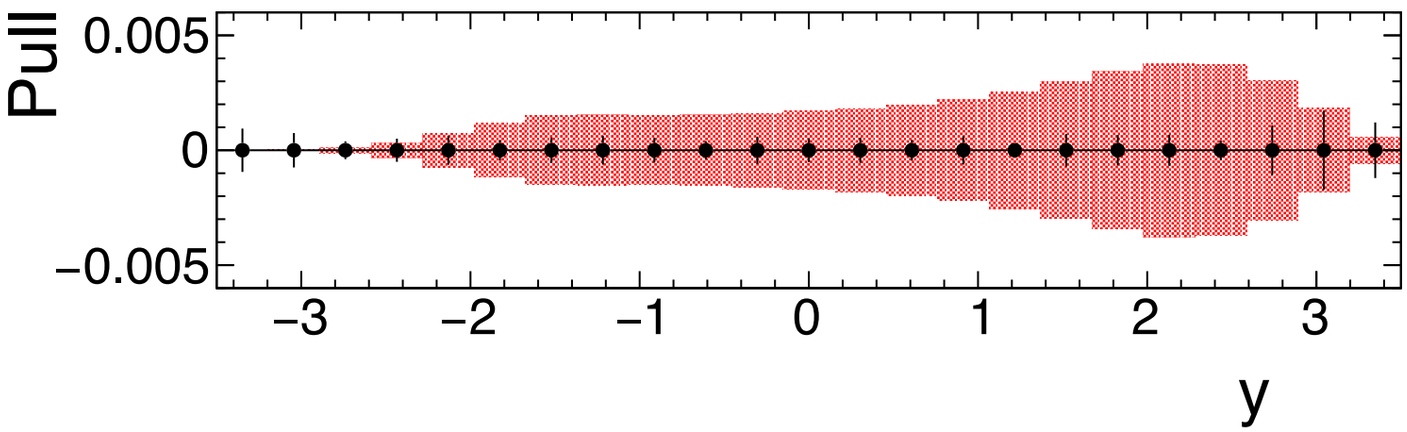
- bias induced by *W* mass variations
- lepton trigger and id efficiencies as function of η_{LAB}
- variation of average *W* p_T as a function of rapidity
- variation of *W* p_T spectrum independently of rapidity

all the variations are negligible wrt PDFs prediction band

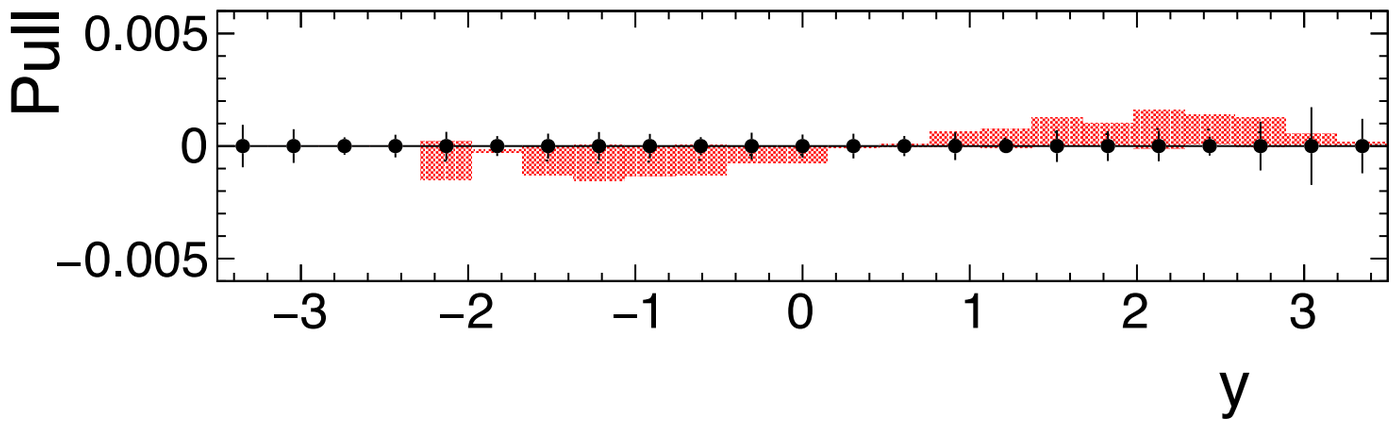
other systematics (i.e. background subtraction can only be assessed with a tailored analysis

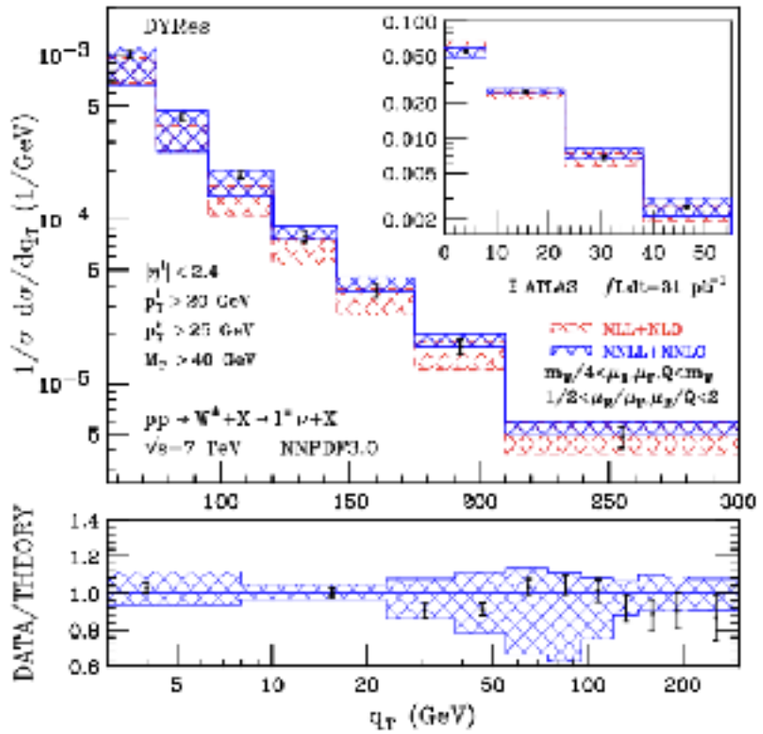
W p_T spectrum reweighting

PDFs band

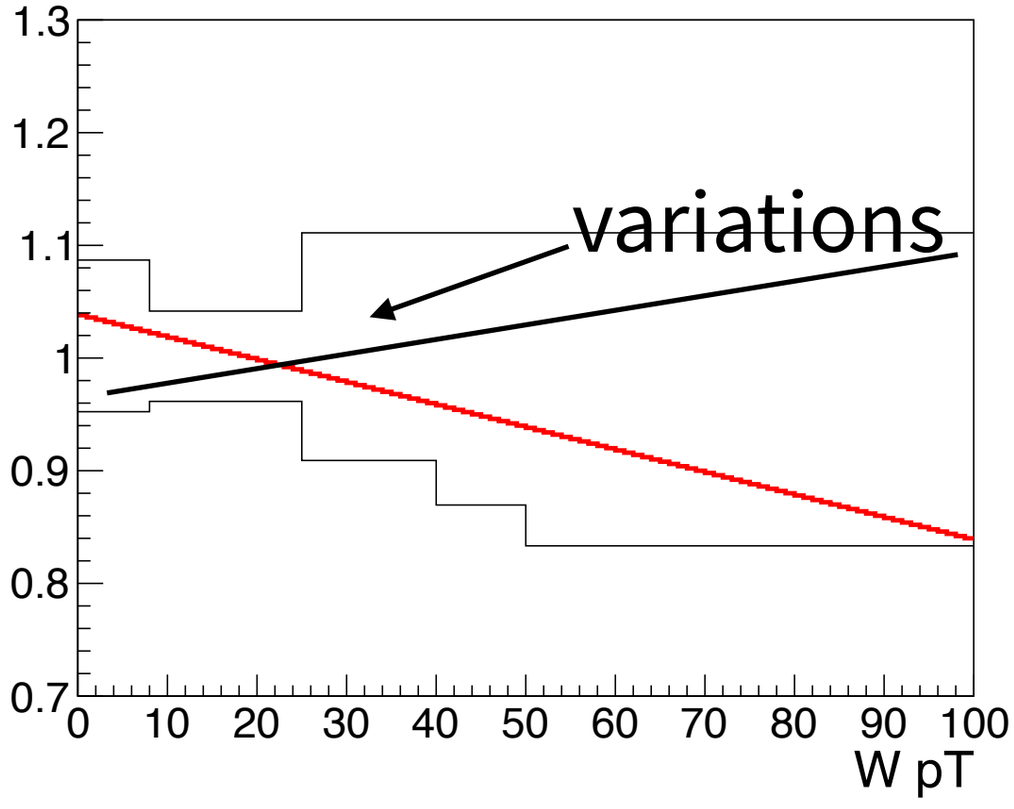


systematics due to *W* p_T reweighting





arXiv:1507.06937



a bunch of conclusions

due to a simple symmetry of the *W* production and decay at LHC, p_T vs η_{LAB} distributions of leptons from *W* decay offer the possibility to measure precisely the *W* rapidity distribution for each helicity state

this measurement depends much less on the correct modelling of the *W* p_T wrt *W* mass measurement

this is interesting for constraining the *W* mass “PDFs uncertainty” and also per se, since such a measurement has never been done