Summary of FWD electrons performance in Run2
ZAi analysis

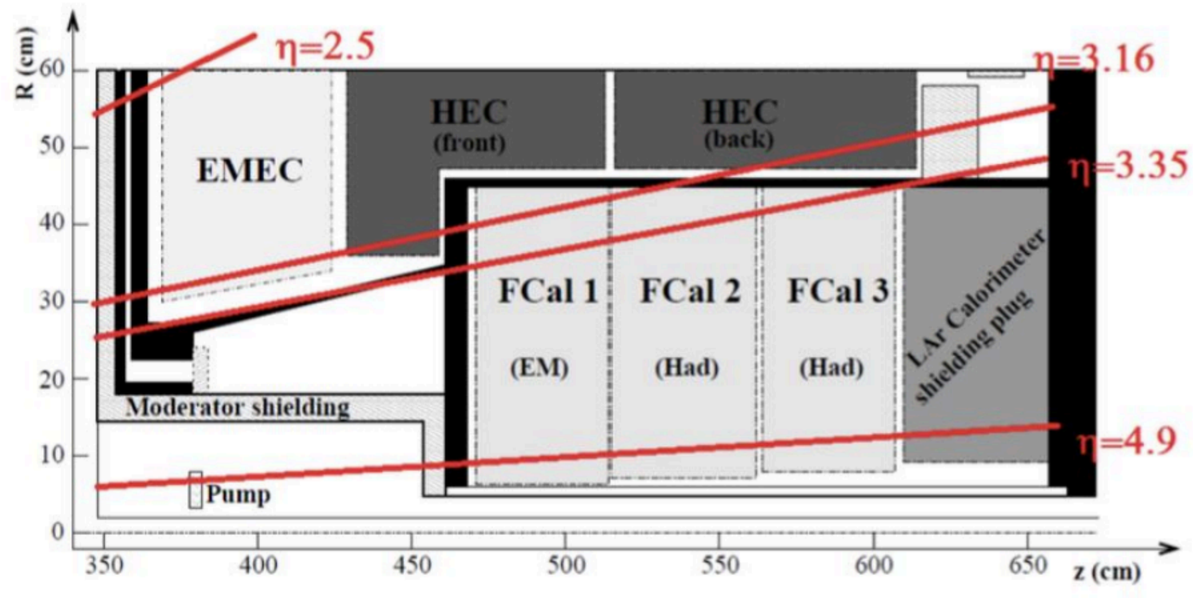
Ludovica Aperio Bella

Forward electrons

Forward Region (|η| > 2.5)

- Electromagnetic end-cap calorimeter (EMEC)
  - $2.5 < |\eta| < 3.2$
- Forward calorimeter (FCAL)
  - $3.2 < |\eta| < 4.9$

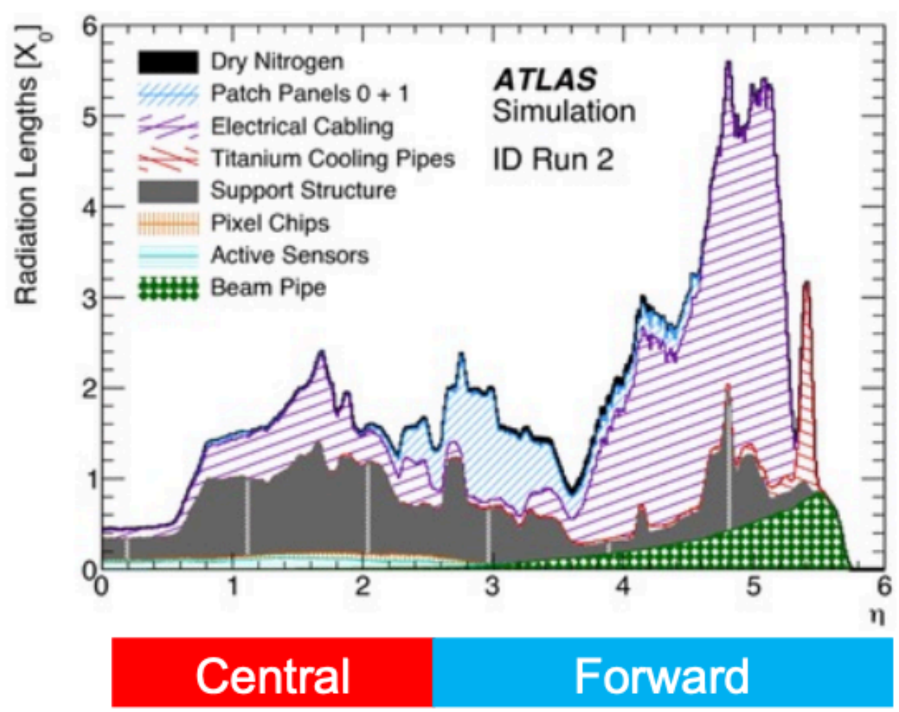
- lower granularity in η:ϕ



- This lies outside of the tracking acceptance of ATLAS!
  - Higher levels of QCD background to deal with.

- Large amounts of passive material to deal with.

- Highly sensitive to Standard Model parameters!

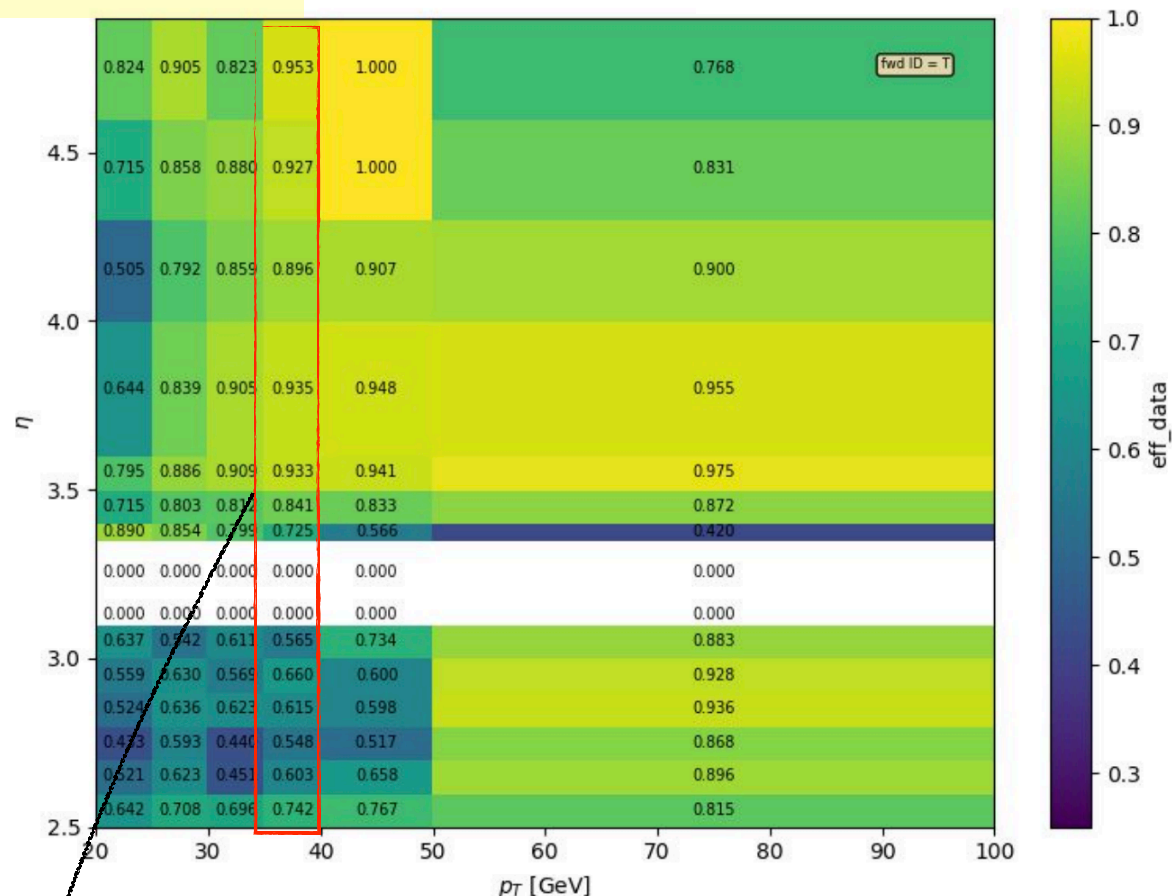


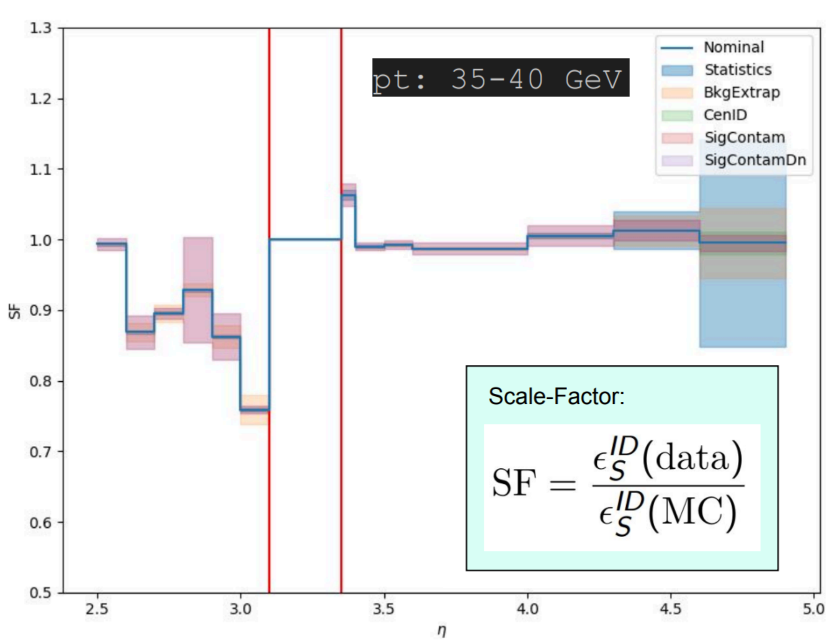
10.17181/CERN.FOZZ.ZP3Q Page 14

Forward electron identification

Lukas talk

data 18 tight Eff

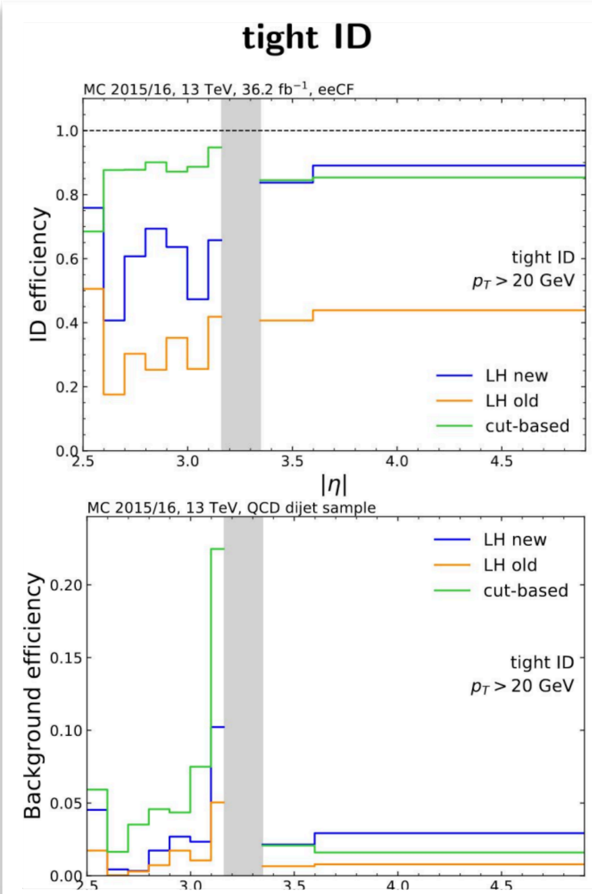




Forward electrons are reconstructed using a topological clustering algorithm, and identified using a likelihood-based discriminant. Tuned with 2015 and 2016 data

- **LH tune NOT officially available in ATHENA release**
- **FudgeFactor applied on MC to have reasonable efficiencies**

tight ID



- Versions:
  - LH new: mc16_20190729
    - (used here)
  - LH old: mc16_20180822
    - (current standard)
  - cut-based: mc15_20150812
- tuned with 2015/16 physics_Main STDM4 data and mc16 Monte-Carlo
- ID efficiency estimated using MCTruthPartClassifier
- Background efficiency estimated using QCD dijet sample to select fake forward electrons

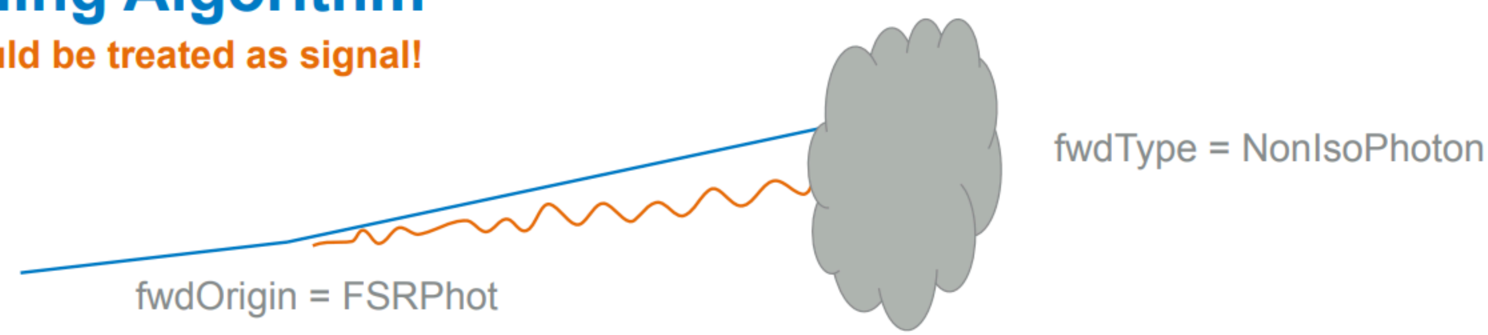
small remark about truth matching

Lukas slides TM

- Truth Matching algorithm need to be apply at analysis level and consistency on all the performance steps.
  - in signal MC we consider reconstructed fwd-El that are also truth matched.
    - the non-truth matched fwd-El are rejected and consider in the bkg estimate.

Truthmatching Algorithm

FSR Photons should be treated as signal!




```
if (!(fwdType == IsoElectron && (fwdOrigin==ZBoson || fwdOrigin==ZorHeavyBoson)) &&
   !(fwdType == IsoPhoton && (fwdOrigin==ZBoson || fwdOrigin==ZorHeavyBoson)) &&
   !(fwdType == BkgElectron && (fwdOriginBkg==ZBoson|| fwdOriginBkg==FSRPhot))) pass = false;
```

does not exist in ntuples for 13 TeV !!!

no-truth matching applying while calibrating fwd-El

→ include fwdType == NonIsoPhoton && fwdOrigin == FSRPhot into truthmatching as true fwd-el

Calibration

- Run2 FWD-Electron strategy follows closely 8TeV one (here) with some improvements :

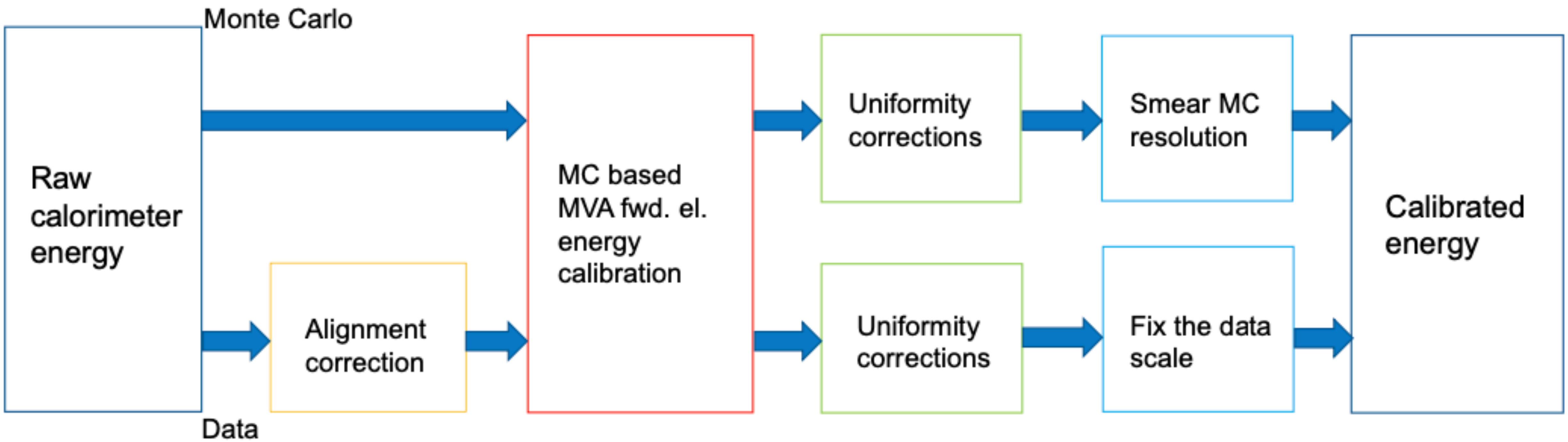


Figure 6: The calibration chain for forward electrons.

(more info Craig Talk)

- Alignement corrections
- MVA:Correcting the raw energy of individual electrons.
- Uniformity correction: Harmonising the energy response of the calorimeter cells.
- INSITU: Matching the mass spectrum of the Z boson in data and Monte Carlo.

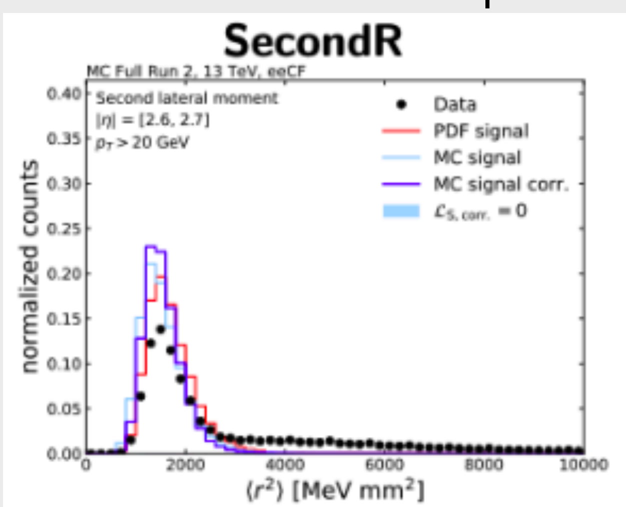
MVA

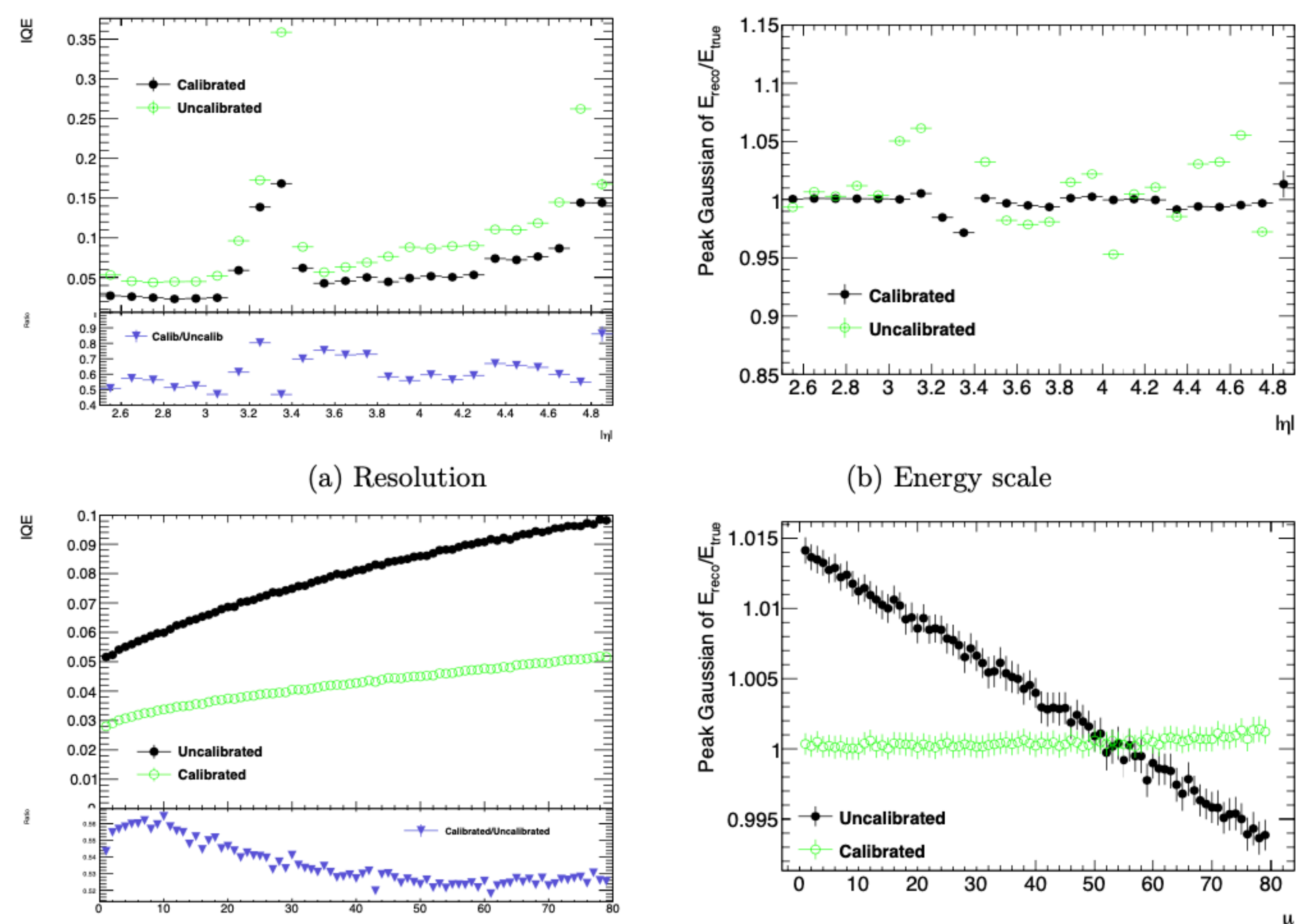
EMEC ($\|\eta\| < 3.15$)	FCal ($\|\eta\| > 3.35$)	Transition Region ($3.15 < \|\eta\| < 3.35$)
E_{raw}	E_{raw}	E_{raw}
η_{cl}	$CentreX/Y/Z$	$CentreX/Y/Z$
ϕ_{cl}		
$\eta\ Modulus\ \Delta\eta$	$\eta\ Modulus\ \Delta\eta$	$\eta\ Modulus\ \Delta\eta$
$\lfloor \eta/\Delta\eta \rfloor$	$\lfloor \eta/\Delta\eta \rfloor$	$\lfloor \eta/\Delta\eta \rfloor$
μ	μ	μ
npv	npv	npv
$< r^2 >$	$< r^2 >$	–
$E_{S_1}^{Max}/E_{S_2}^{Max}$	$< \rho^2 >$	–
$\phi\ Modulus\ \frac{2\pi}{16}$	λ_{centre}	–

Table 3: The input variables used for training the BDTs. N.B μ is defined here as the actual number of interactions per bunch crossing.

In MC MVA greatly improve linearity and resolution of FWD electron ~40%

crucial role of shower shape correction





(a) Resolution

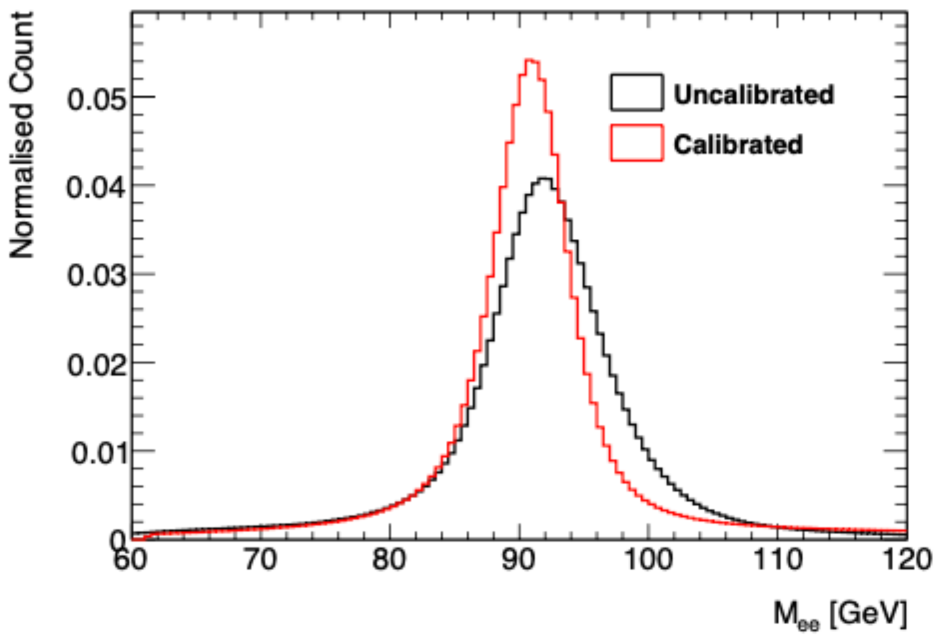
(b) Energy scale

(c) Resolution as a function of pileup.

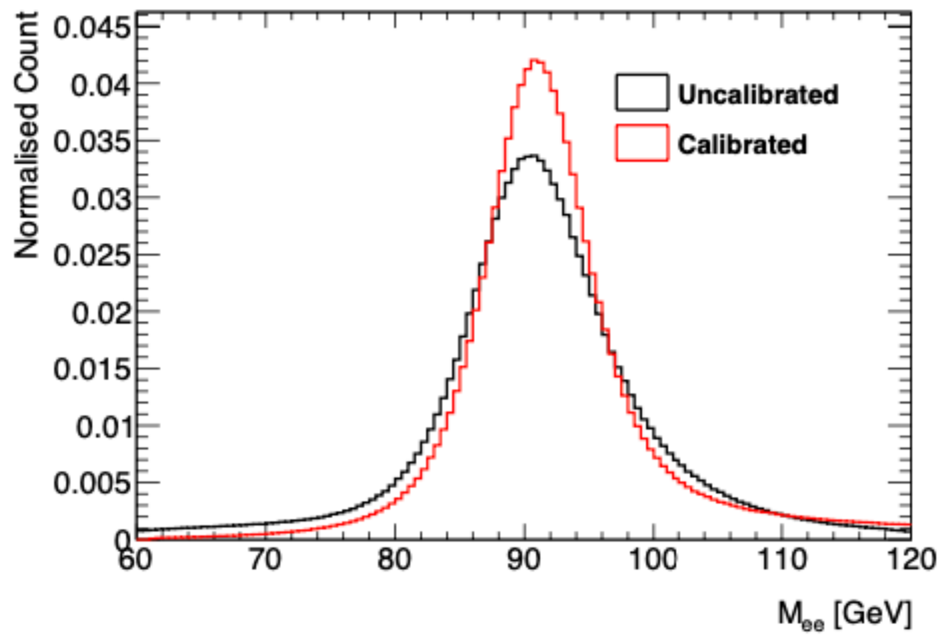
(d) Energy scale as a function of pileup.

Post MVA m_{ee}

(more info Craig Talk)



(a) EMEC

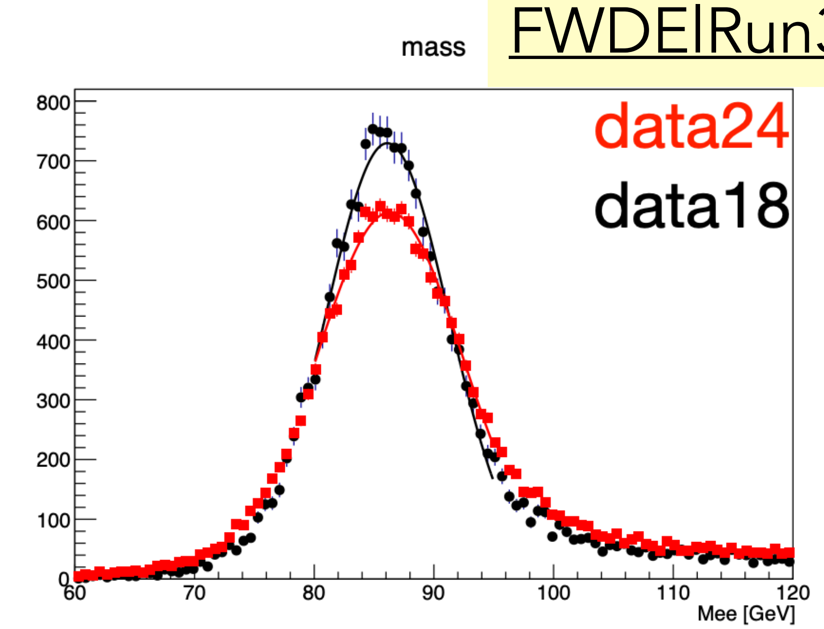


(b) FCal

2017	Fitted Peak (GeV)	IQE (Calibrated Improvement)
Data Uncalibrated	90.62	3.79
Data Calibrated	90.25	3.34 (11.9%)
Signal Uncalibrated	91.46	3.52
Signal Calibrated	91.13	2.82 (19.9%)

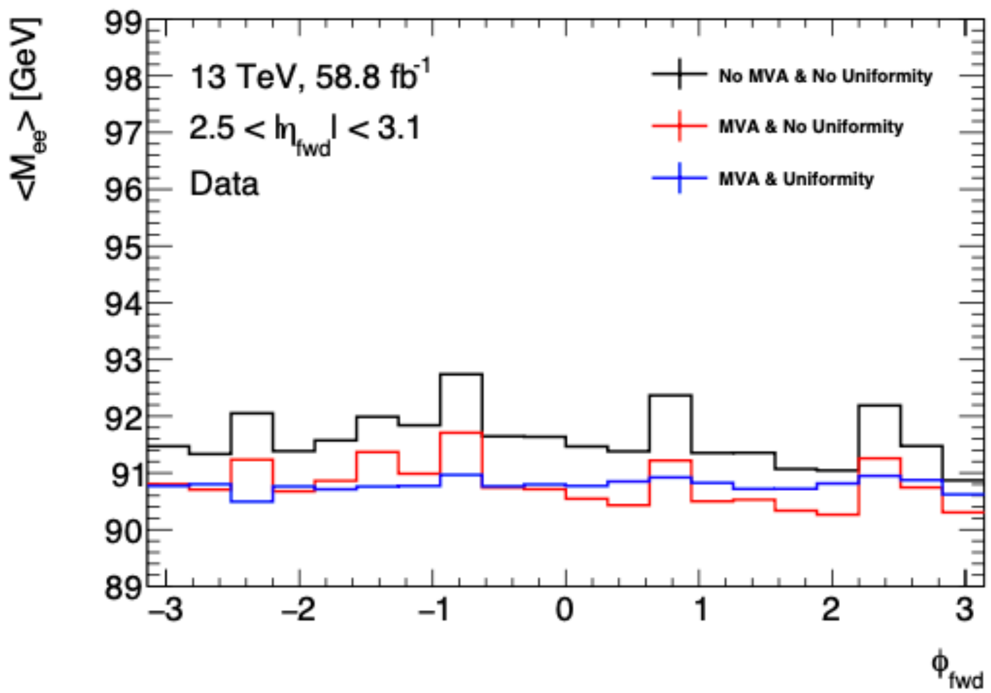
MC much more optimistic then data because of missing pileup noise

FWDElRun3

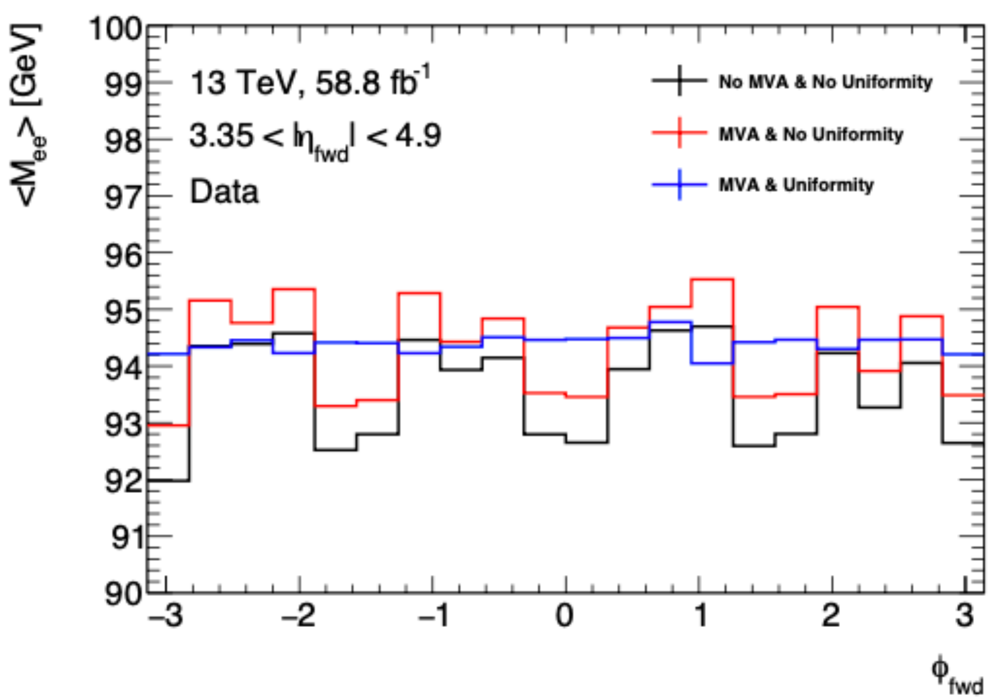


Non - uniformity correction

(more info Craig Talk)

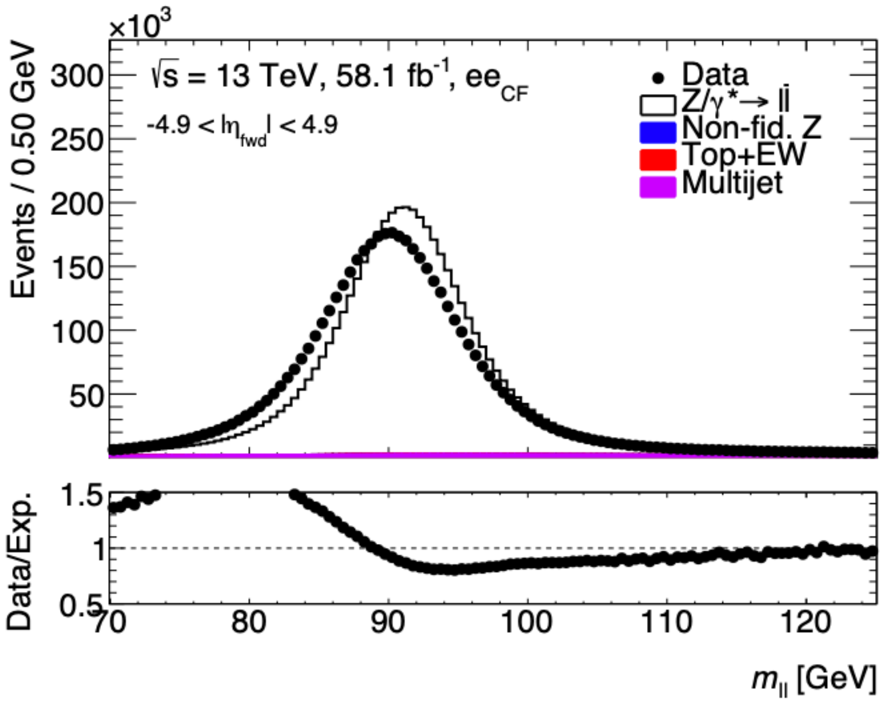


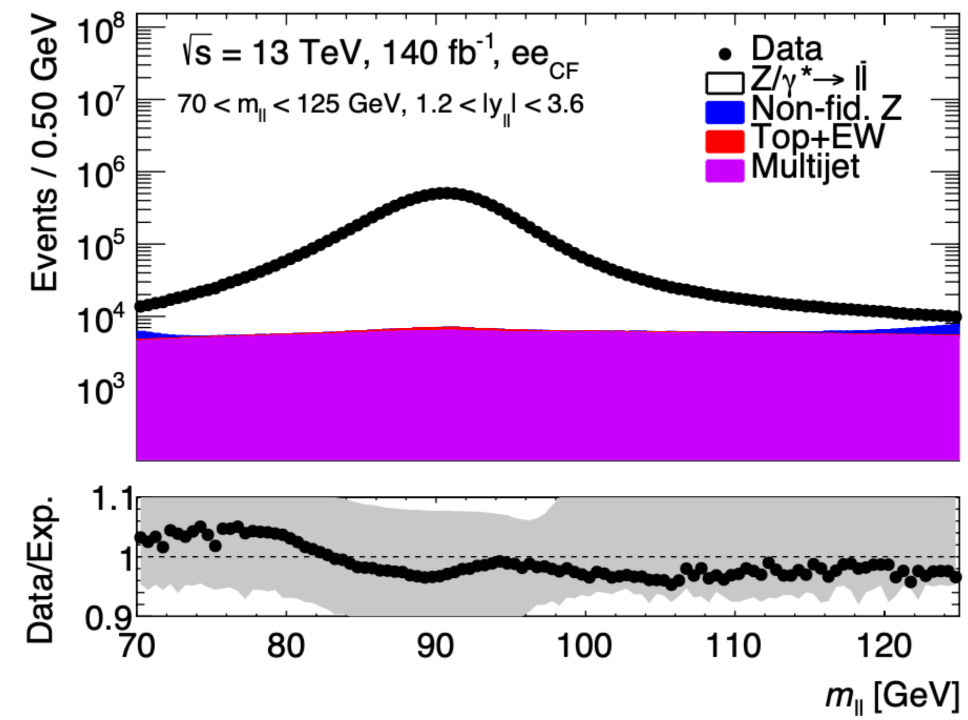
(a) Uniformity in data in the EMEC (



- Large modulation vs ϕ seen in EMECs (partially correct by MVA)
  - especially pronounced in η bin known to have large unknown material effects
  - Derive energy scale corrections based on fitted mean
    - Inter-calibrate data-data and MC-MC such that energy scale is uniform vs ϕ in each η bin

In situ energy calibration





Post-MVA + uniformity signal MC

Template function

Top + EW + MJ

$$T_{MC}(\mathrm{m}) \rightarrow \mathrm{f}_{\mathrm{Data}}(\mathrm{m}) = \mathrm{T}_{\mathrm{MC}}(\mathrm{m}) \otimes DSCB(m; \mu, \sigma, \alpha_L, \alpha_R, n_L, n_R) + T_{Bkg}(m)$$

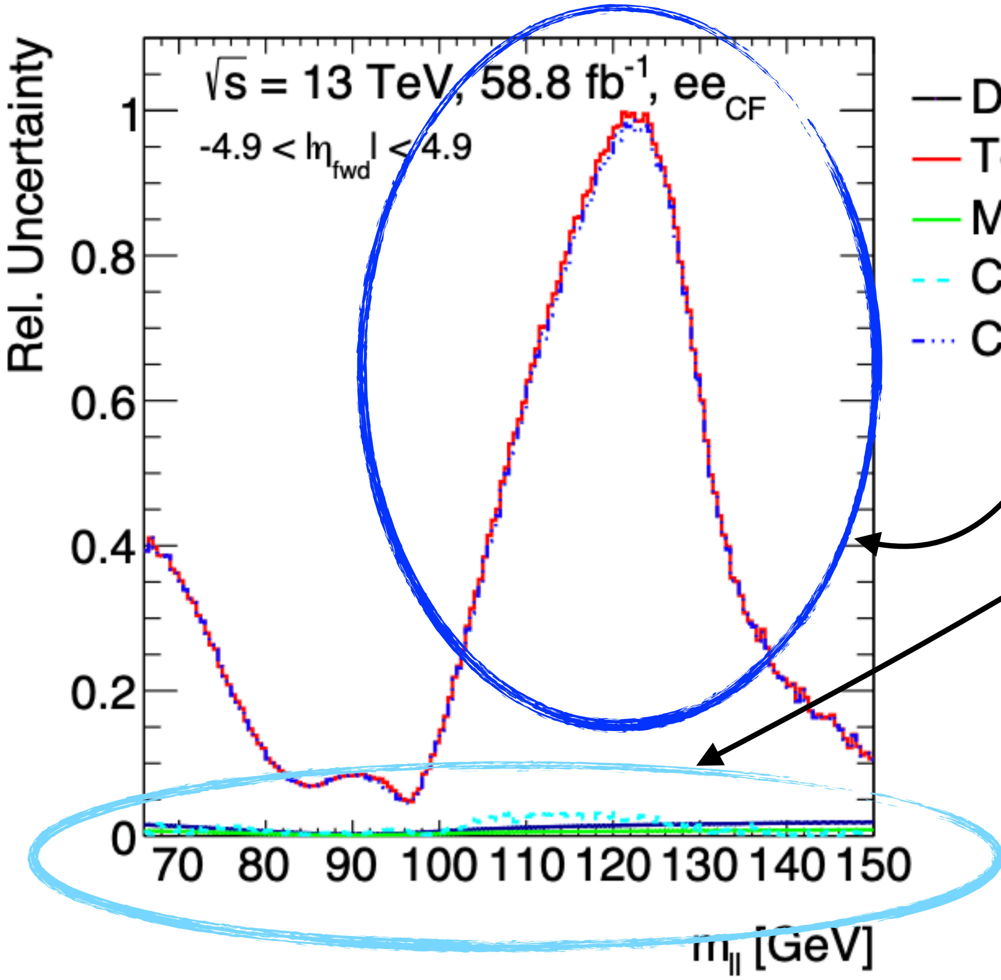
Signal MC becomes a function approximating data

Fit to the actual data distribution

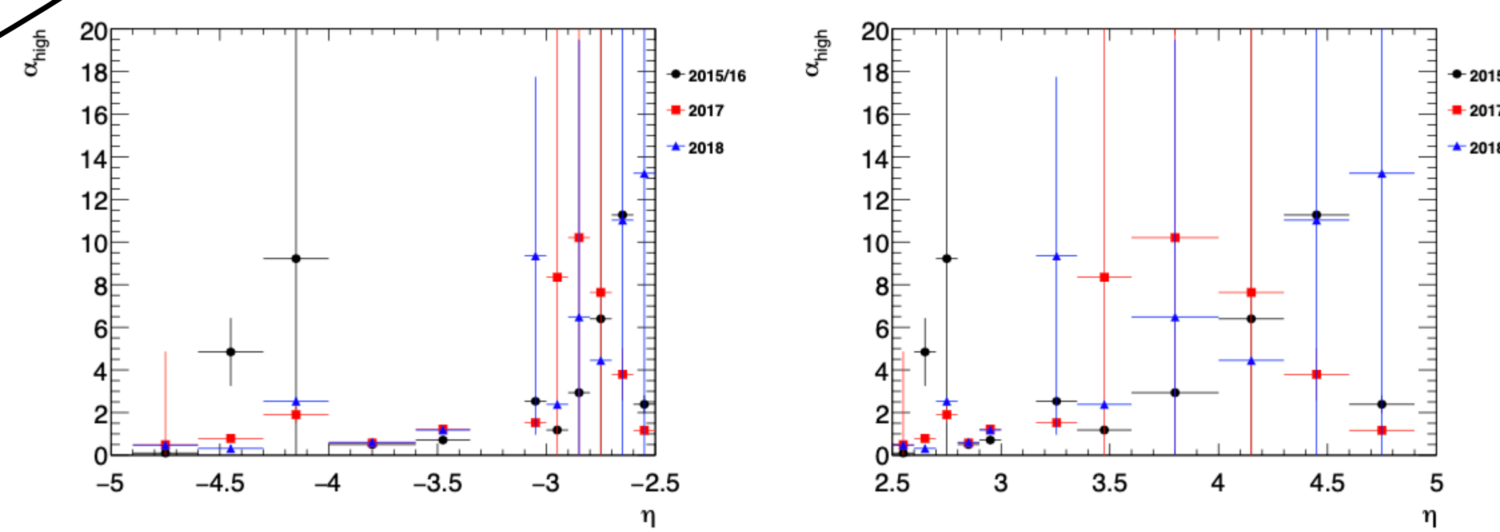
$$f(m;\mu,\sigma,\alpha_L,\alpha_U,n_L,n_U) = \begin{cases} A_L \times \left(B_L - \frac{m-\mu}{\sigma}\right)^{-n_L} & \frac{m-\mu}{\sigma} < -\alpha_L \\ \exp\left(-\frac{(m-\mu)^2}{\sigma^2}\right) & -\alpha_L < \frac{m-\mu}{\sigma} < \alpha_U \\ A_U \times \left(B_U - \frac{m-\mu}{\sigma}\right)^{-n_U} & \frac{m-\mu}{\sigma} > \alpha_U \end{cases}$$

(more info Craig Talk)

In situ energy calibration



- Forward electron calibration is by far the leading systematic.

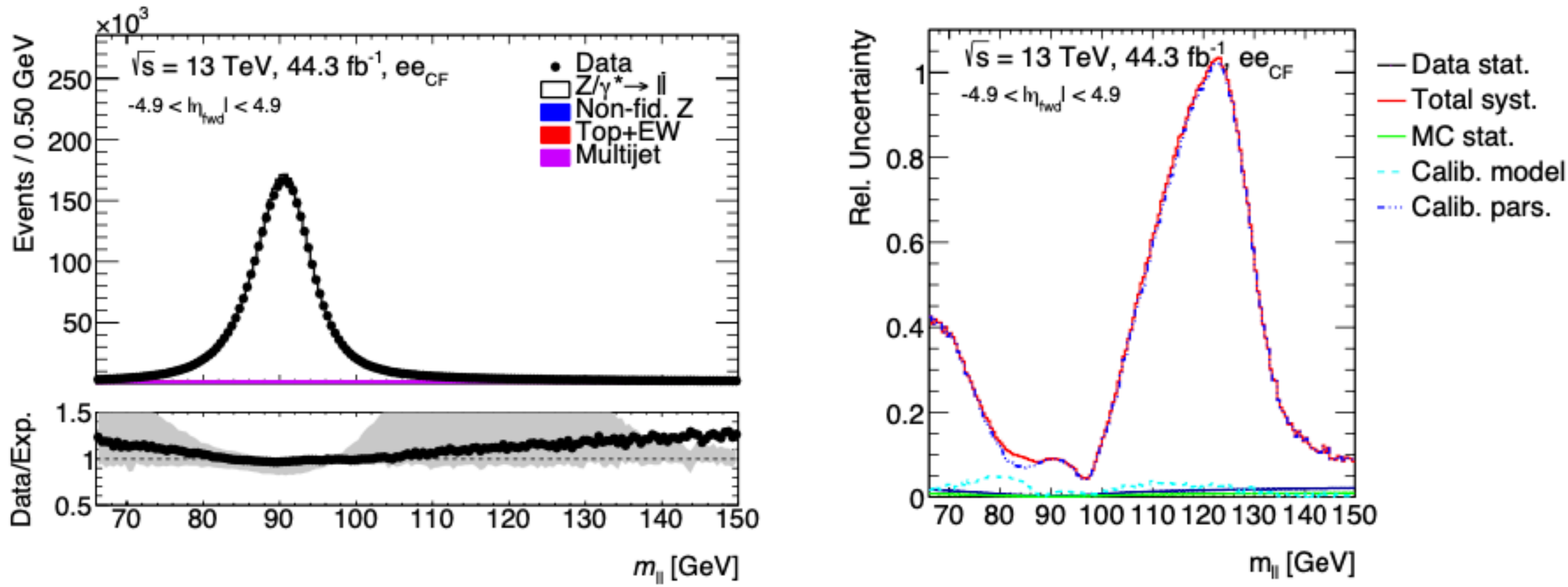


(g) Fitted α_U for $\eta < 0$. (h) Fitted α_U for $\eta > 0$.

$$f(m;\mu,\sigma,\alpha_L,\alpha_U,n_L,n_U) = \begin{cases} A_L \times (B_L - \frac{m-\mu}{\sigma})^{-n_L} & \frac{m-\mu}{\sigma} < -\alpha_L \\ \exp\left(-\frac{(m-\mu)^2}{\sigma^2}\right) & -\alpha_L < \frac{m-\mu}{\sigma} < \alpha_U \\ A_U \times (B_U - \frac{m-\mu}{\sigma})^{-n_U} & \frac{m-\mu}{\sigma} > \alpha_U \end{cases}$$

several DSCB Fit parameters unconstrained by the fit resulting in very big variation

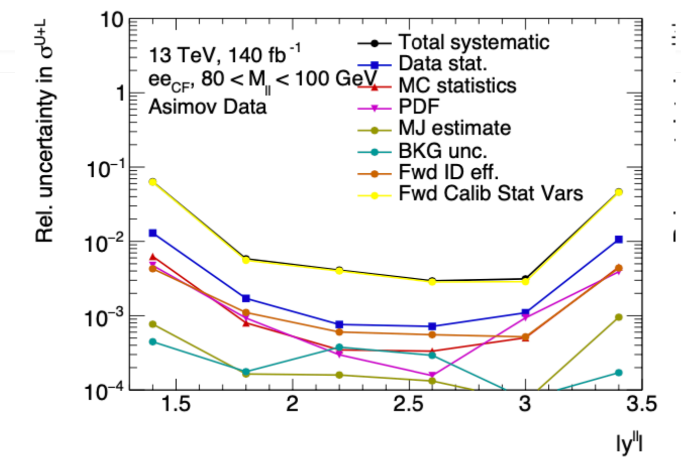
enlarging sin2tw extraction above 125GEV ?



We can do better

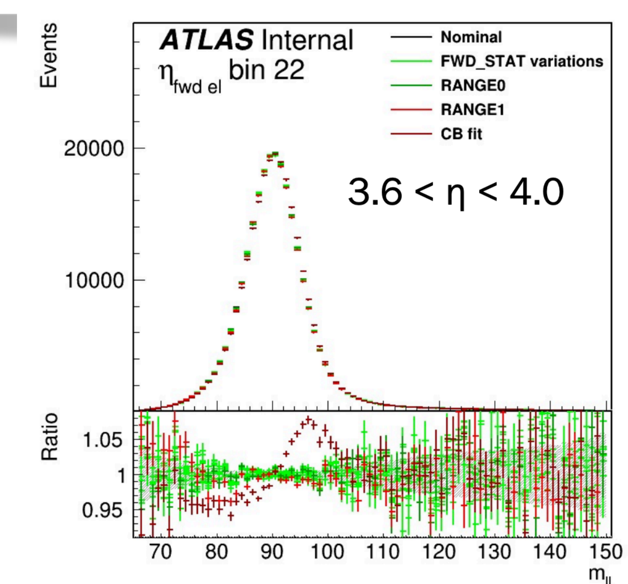
from here

CF WMA - Observations



- On pole, we reach a total systematic uncertainty of 1% in A_9!
  - *I'm sure we can do better though* 😉
- Forward electron calibration is by far the leading systematic.
  - *Effect of variations to the fit m_{ll} range still to be evaluated.*
  - *Sensitivity at high y_{ll} could be improved by merging FCal bins in the calibration.*
  - *Effect of parameter variations can most likely be improved (e.g changing allowed fit ranges and/or fixing parameters with large uncertainties). Personally I'd look at fixing n_high/low and allowing alpha to float.*
- MJ may be possible to reduce further.
  - *Use fake factors for full run 2 rather than individual years. Unlikely to yield large improvements since CF MJ >> CC MJ.*
  - *Fix issues with FF stat variations to bring it down to level of other variations. The fit will then most likely consider these variations as well.*

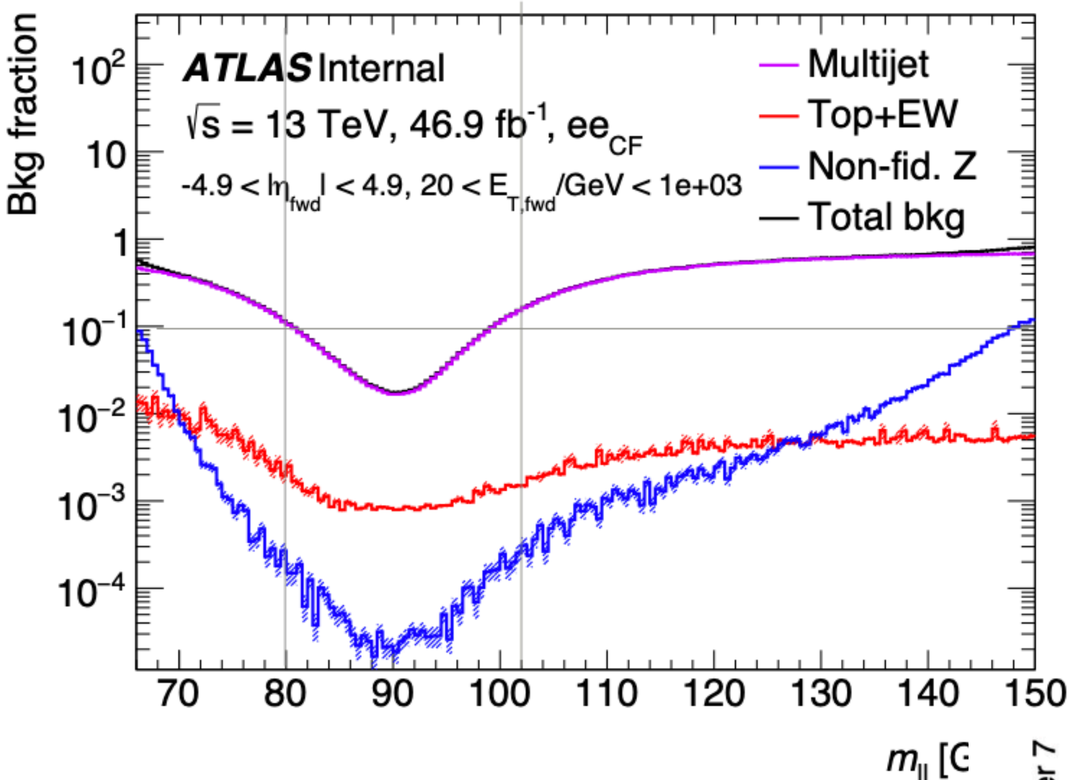
We could improve simply the in situ model by fixing some of the parameter in the FIT ! —> the second dominant sys in the calibration procedure is coming for changing for CB to DSCB model only few % impact in the Xsection



BACKUP

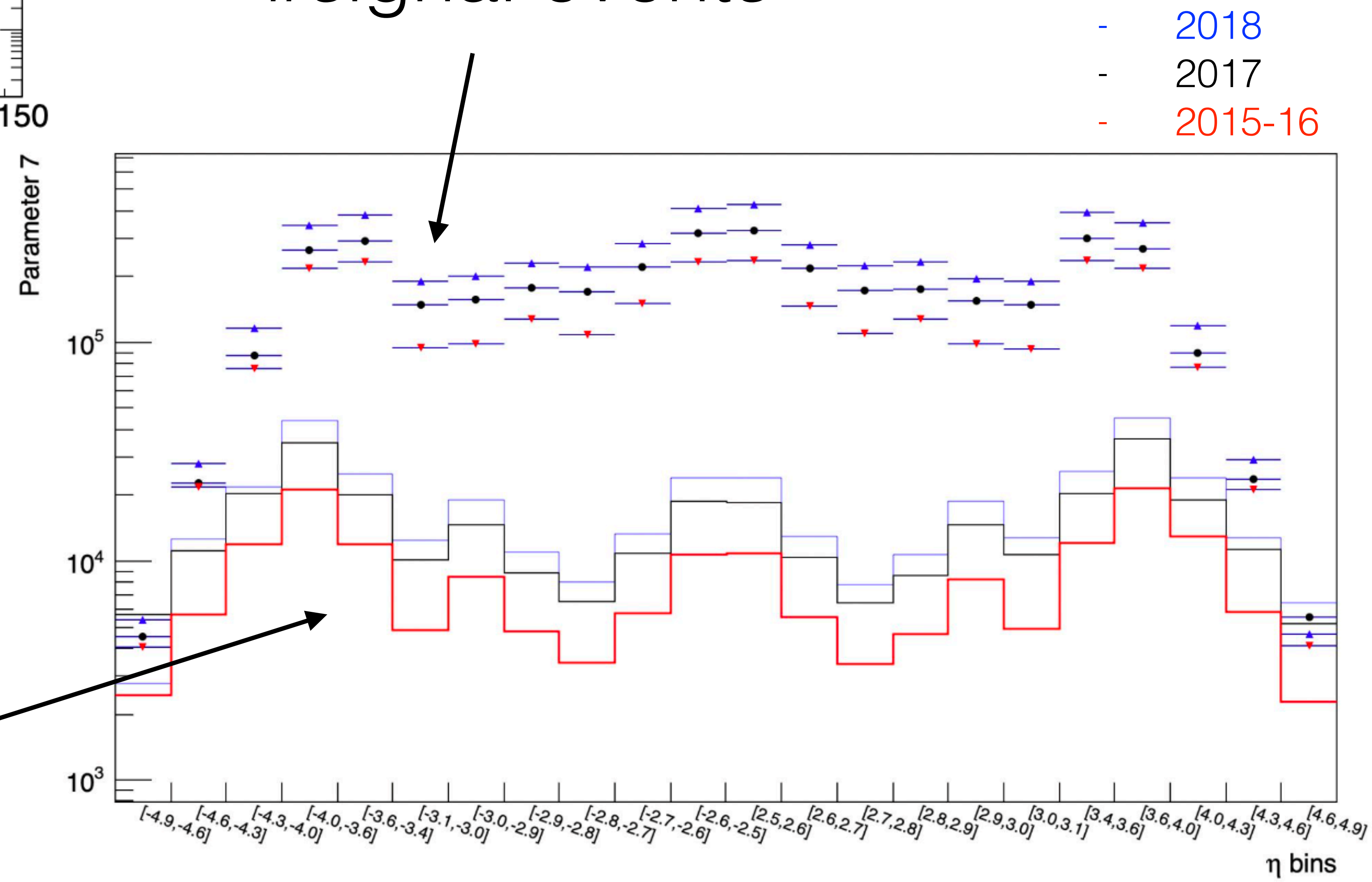
Craig Freiburg: https://indico.cern.ch/event/1327610/contributions/5587221/attachments/2731511/4748676/Freiburg23_Craig.pdf

Not negligible MJ



in calibration chain
mll[66 - 150]GeV

#signal events



#bkg events

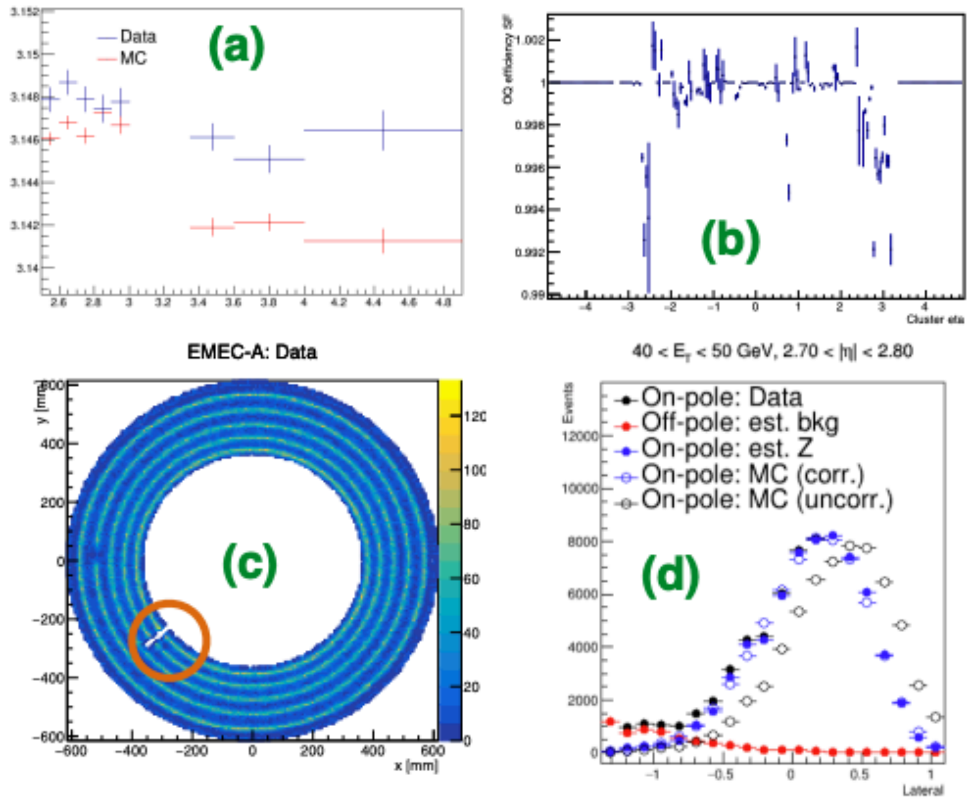
as a reminder very complicated fwd electron calibration/ correction @8TeV

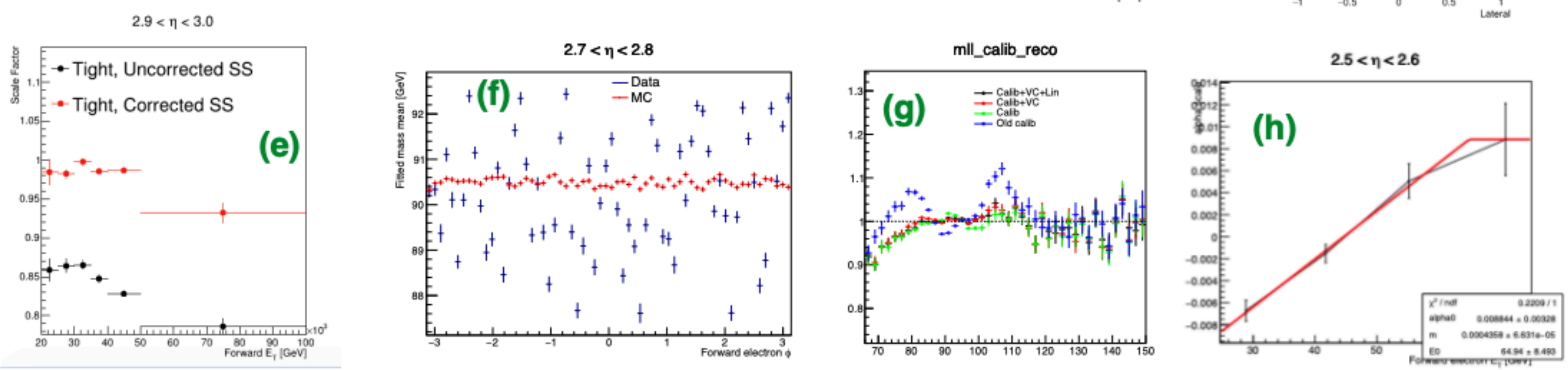
8TeV strategy described here(CDS)

Reminder: Fwd Electron Performance

3

- Several new corrections applied to address the issues observed
  - (a) Alignment corrections
  - (b) OQ scale factors
  - (c) Removal of regions with HV or other unknown DQ issues
  - (d) Shower shape corrections
  - (e) New ID scale factors
  - (f) Phi / X-Y energy inter-calibration
  - (g) Crystal Ball based calibration for mis-modelled material effects
  - (h) Energy response linearity correction





[summary of Run1 fwd electron performances for Ai analyis](#)

Reminder: Fwd Electron Performance

3

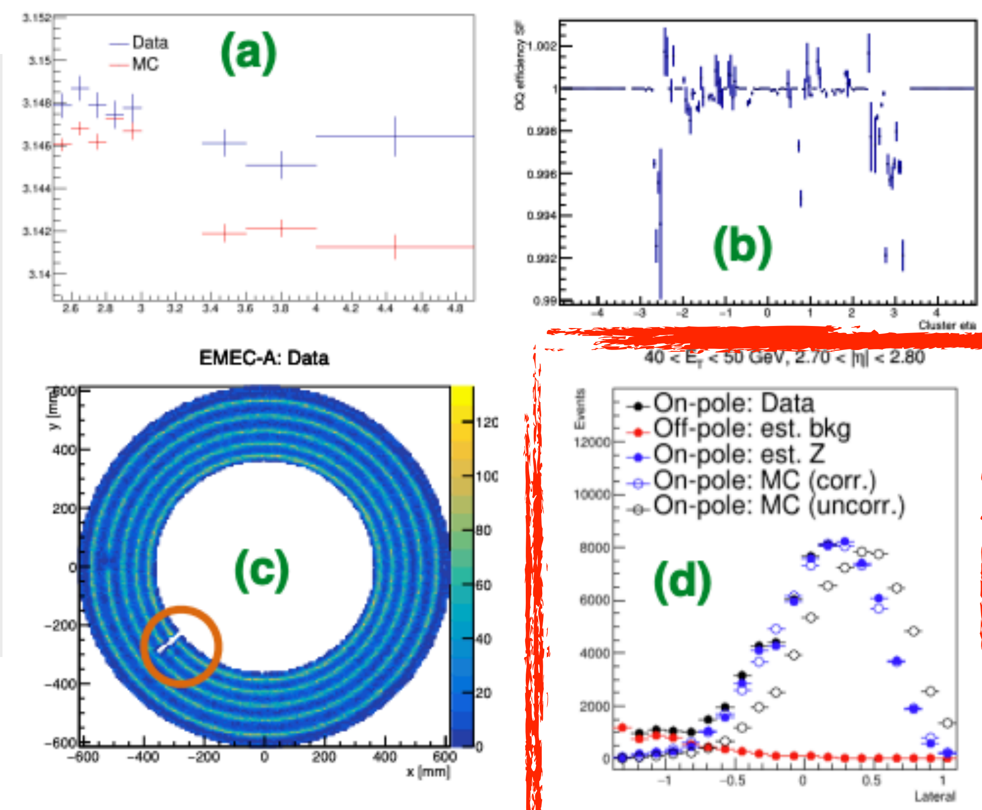
we expect MVA to help with:

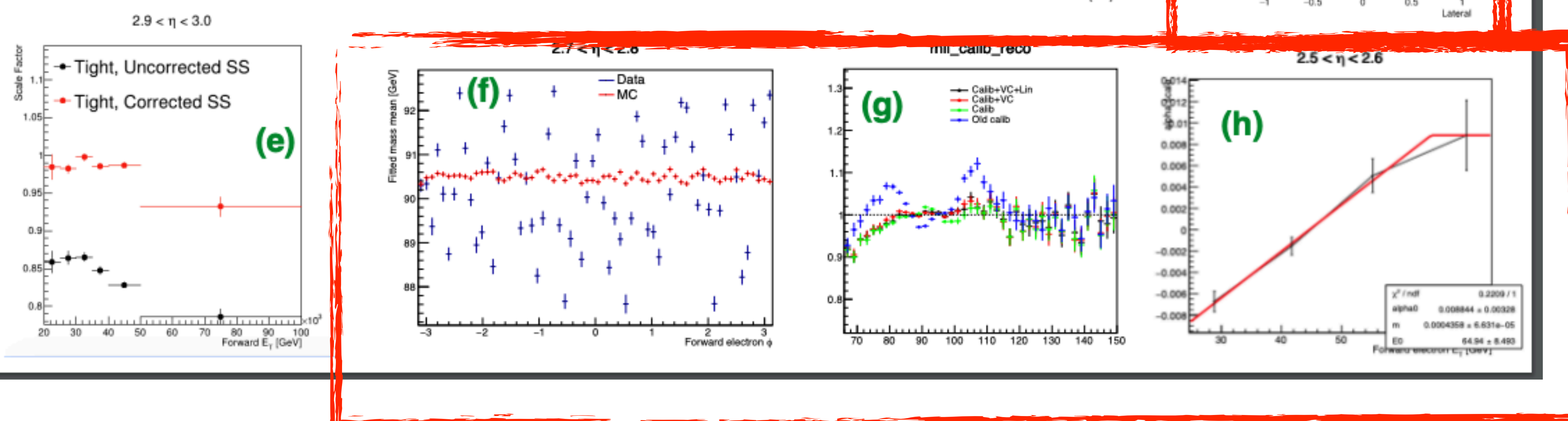
(d)dependence of calibration on Shower shape

(f) non uniformity

(g)more gaussian tail on the energy response

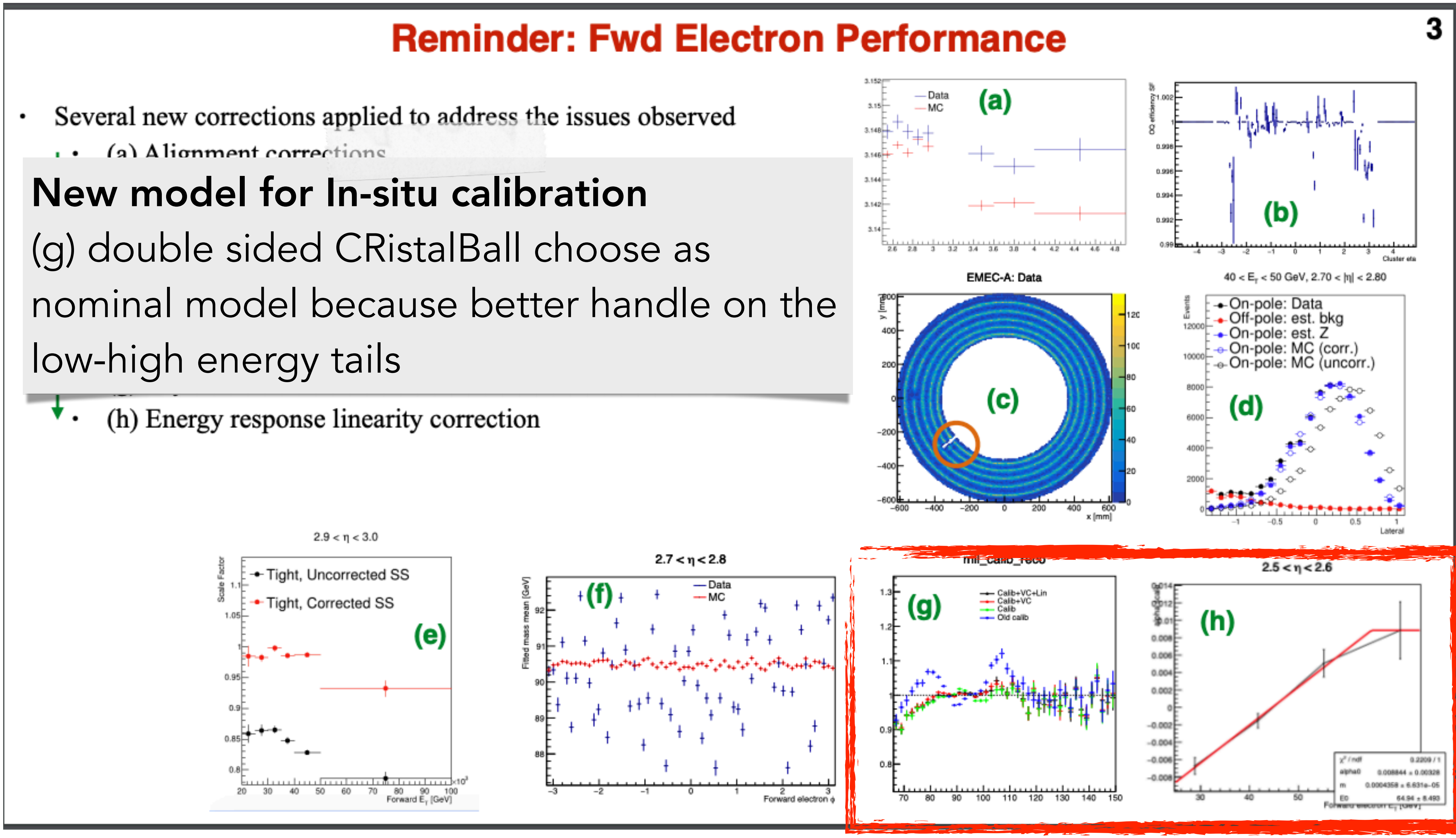
(h)general energy scale linearity





changes wrt 8TeV

summary of Run1 fwd electron performances for Ai analyis

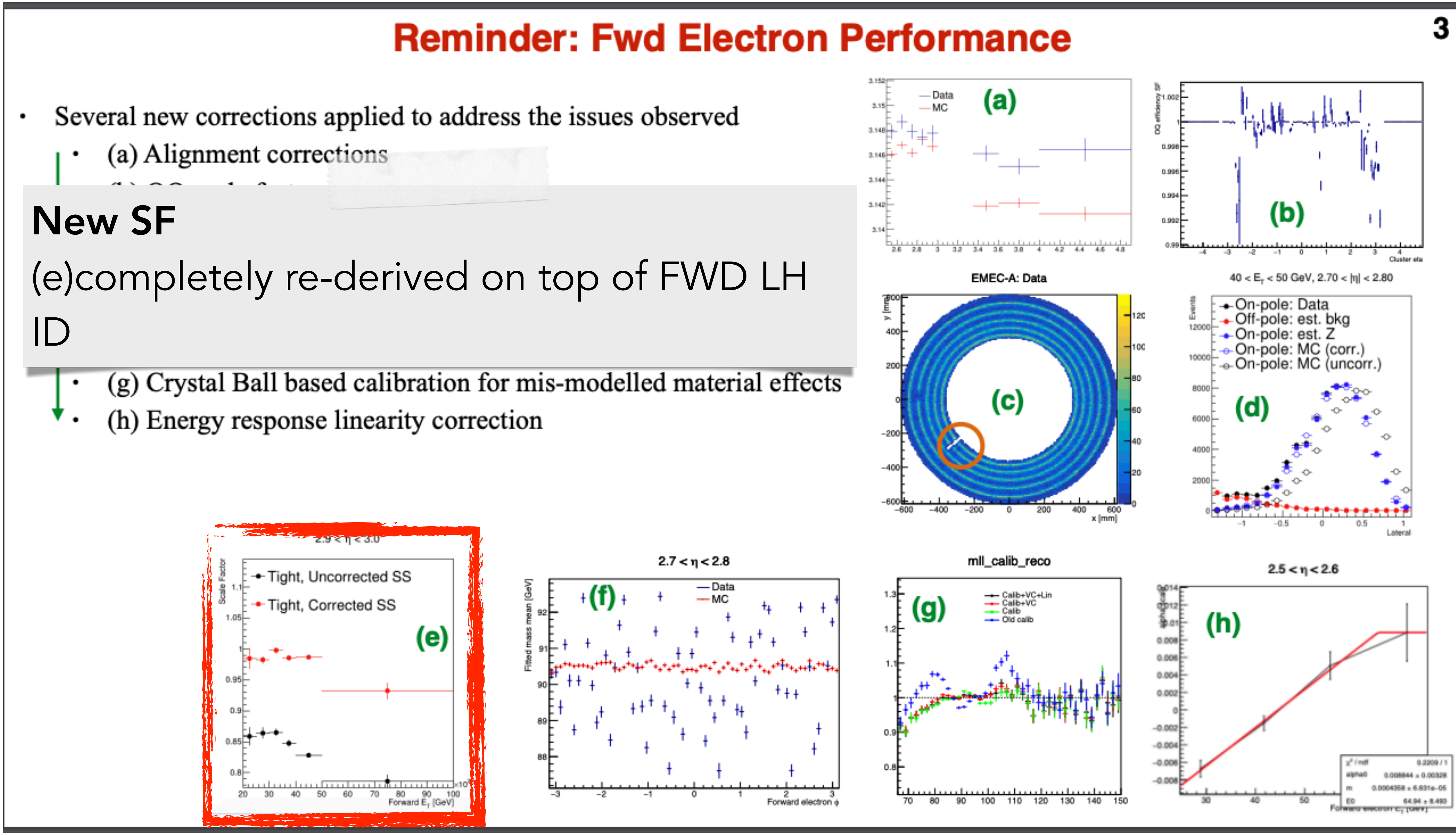


New model for In-situ calibration

(g) double sided CRistalBall choose as nominal model because better handle on the low-high energy tails

changes wrt 8TeV

summary of Run1 fwd electron performances for Ai analyis

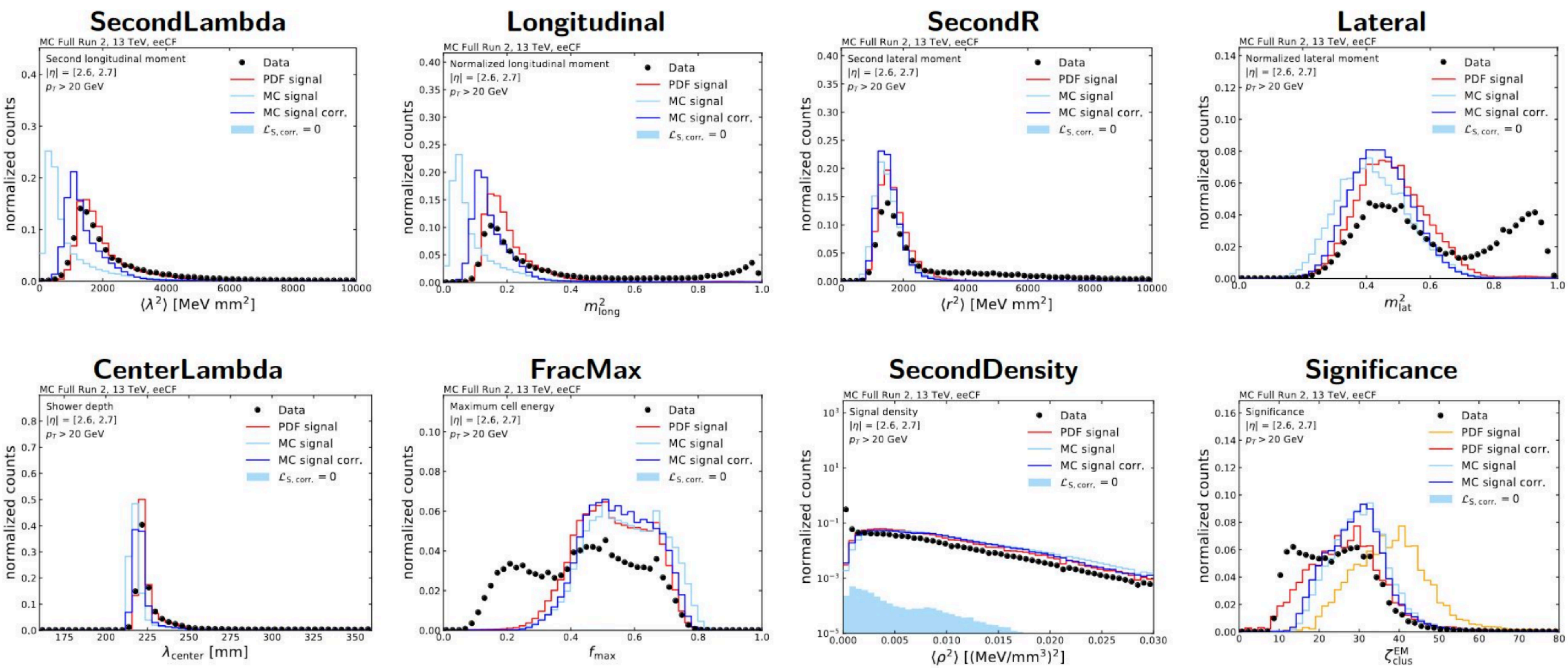


New SF

(e)completely re-derived on top of FWD LH ID

Shower Shapes

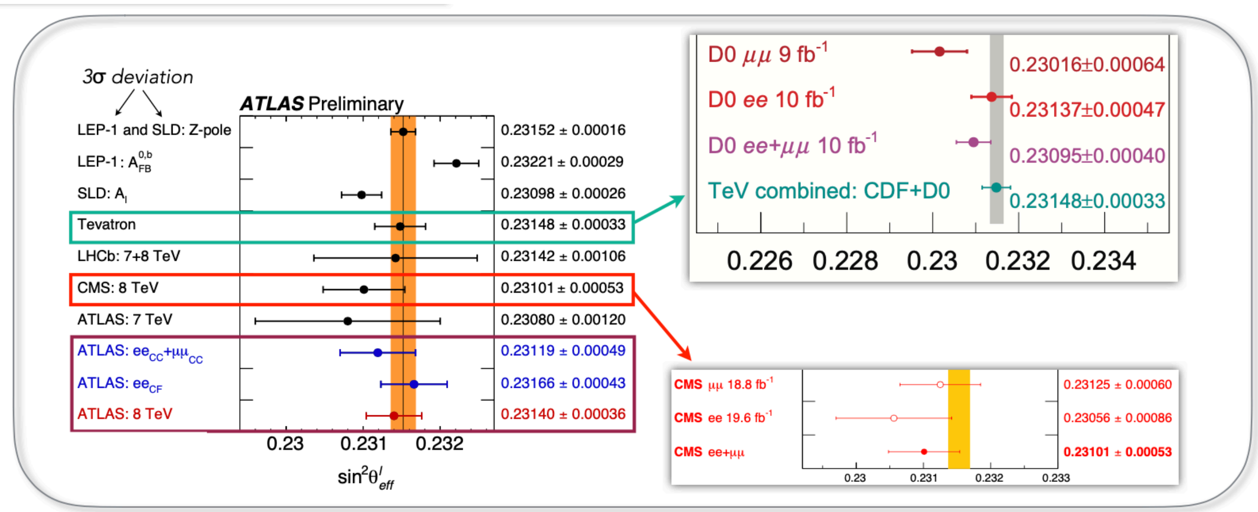
after applying fudge factors (in EMEC)



Channel	ee_{CC}	$\mu\mu_{CC}$	ee_{CF}	$ee_{CC}+\mu\mu_{CC}$	$ee_{CC}+\mu\mu_{CC}+ee_{CF}$
Central value	0.23148	0.23123	0.23166	0.23119	0.23140
			Uncertainties		
Total	68	59	43	49	36
Stat.	48	40	29	31	21
Syst.	48	44	32	38	29
			Uncertainties in measurements		
PDF (meas.)	8	9	7	6	4
p_T^Z modelling	0	0	7	0	5
Lepton scale	4	4	4	4	3
Lepton resolution	6	1	2	2	1
Lepton efficiency	11	3	3	2	4
Electron charge misidentification	2	0	1	1	< 1
Muon sagitta bias	0	5	0	1	2
Background	1	2	1	1	2
MC. stat.	25	22	18	16	12
			Uncertainties in predictions		
(MMHT) PDF (predictions)	37	35	22	33	24
QCD scales	6	8	9	5	6
EW corrections	3	3	3	3	3

x 10^{-5}

ee_{CF} is most precise channel [1.5 M of events (13.5M ee+μμ)
measurement uncertainty 36 x 10^{-5}



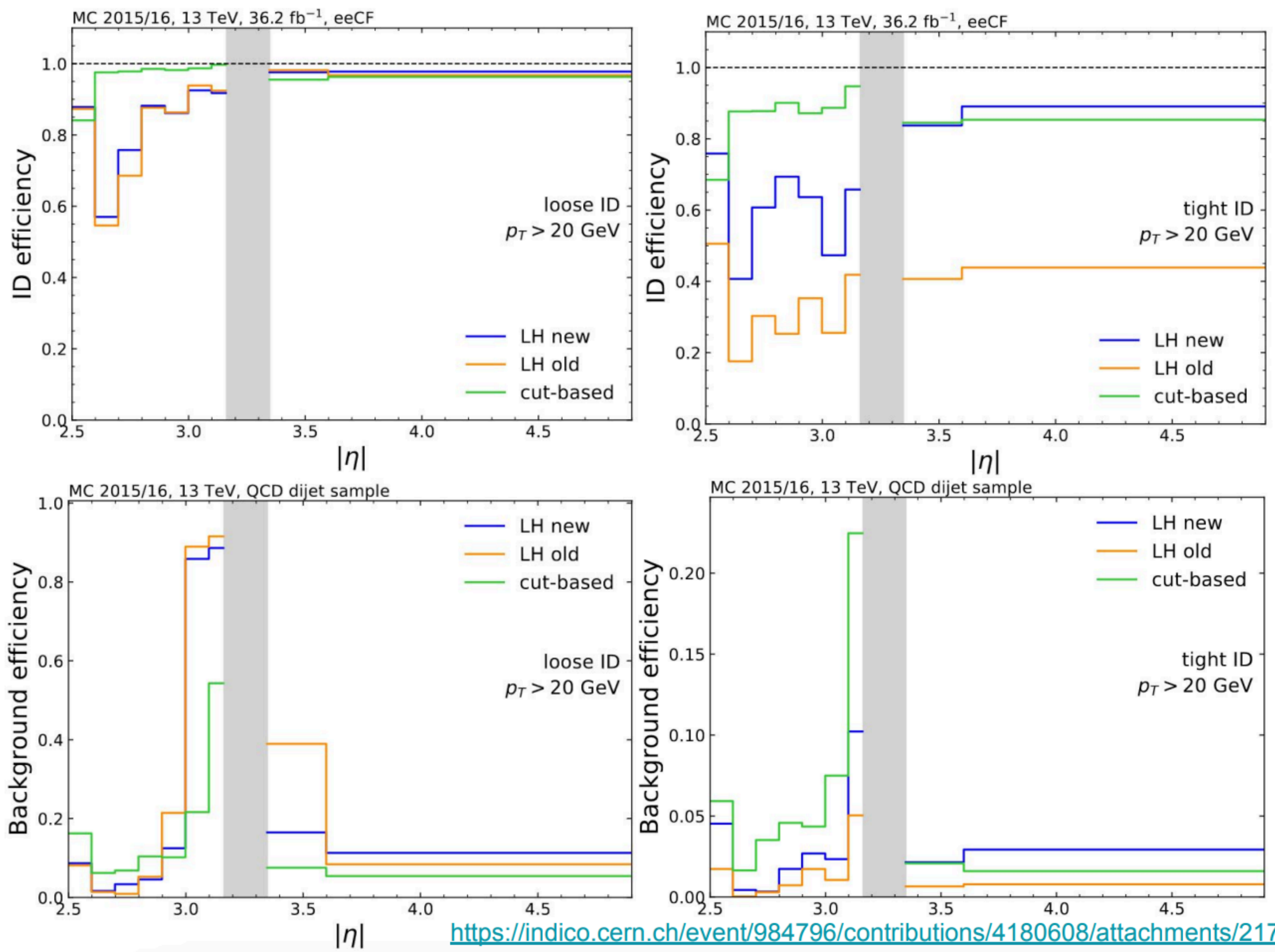
LH ID for FWD electron

Lukas talk

LH Working Point Versions

ID and Background Efficiencies

loose ID **tight ID**



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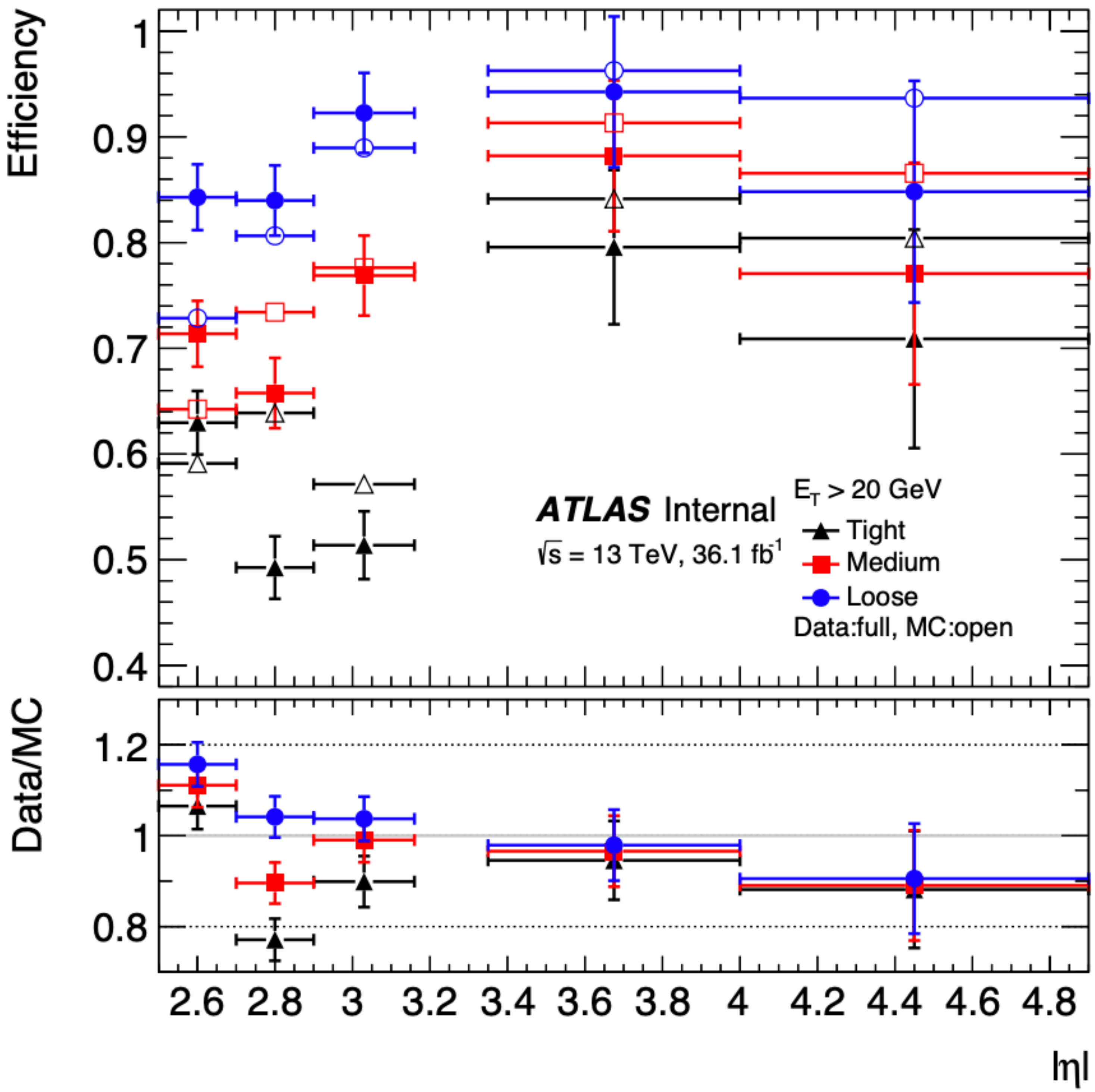
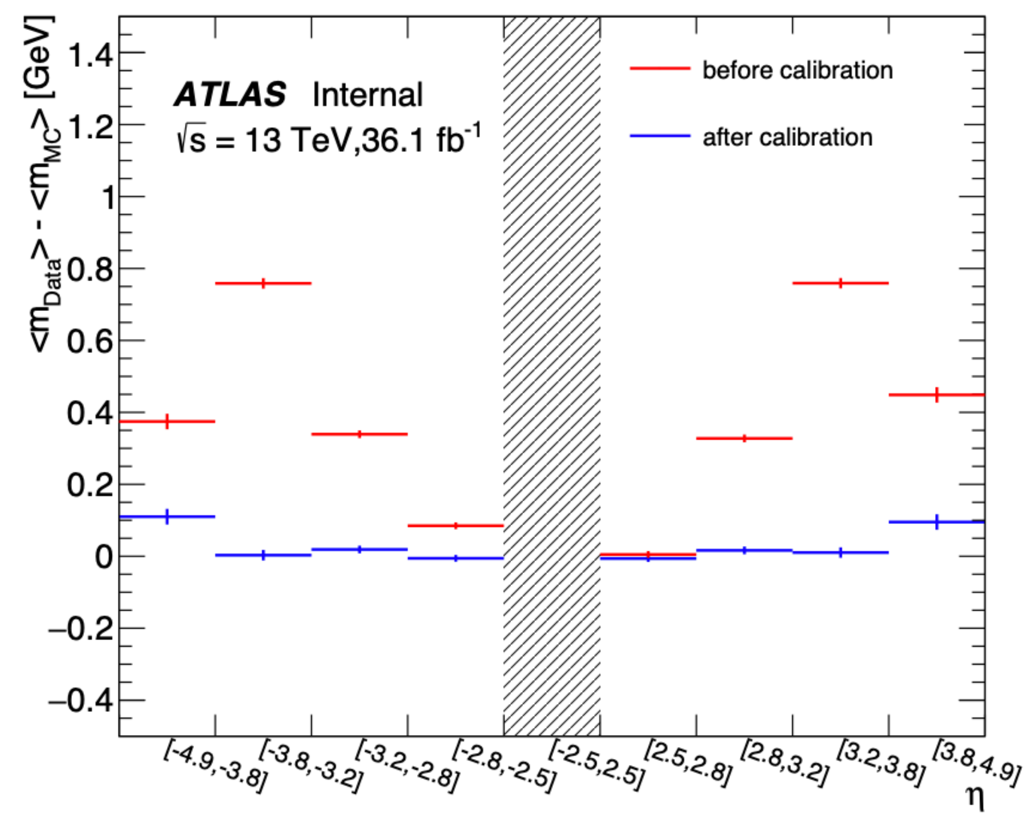
https://indico.cern.ch/event/984796/contributions/4180608/attachments/2171408/3666061/210114_fwd_electron_identification_mh.pdf

DESY. fwd eID SFs | Lukas Bayer https://indico.cern.ch/event/999892/contributions/4199454/subcontributions/326621/attachments/2180678/3683535/210129_update_mh.pdf 4

FWD electron performance data15-16

Public plot 2019



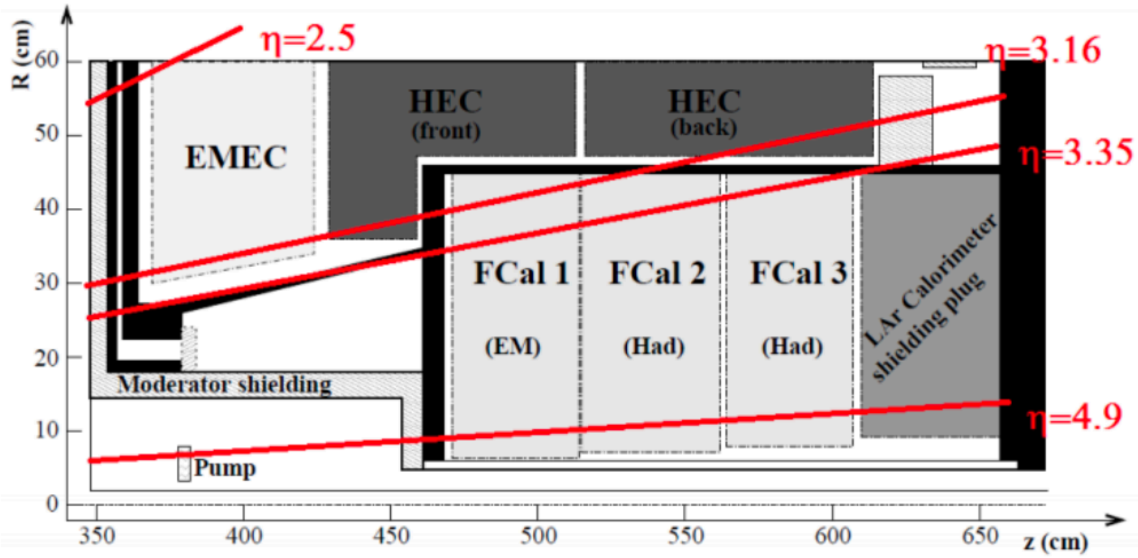


some references

- InsituCalib sumamry (June2022)
- Julian Inter-claibration :Dec2019 JAn2020 January2020 ;Run1 - Run2 diff ; Marc2020 ; Apr2020 ; May2020 —> BCID correction not needed.
- Alignemet: alignement from Julian ; simulation Meeting ; alignemenet 2
- Quality cut: QT 13TeV Manuell offman Nov2020 ; Dec2020

Definition of crack region

Detector Overiew

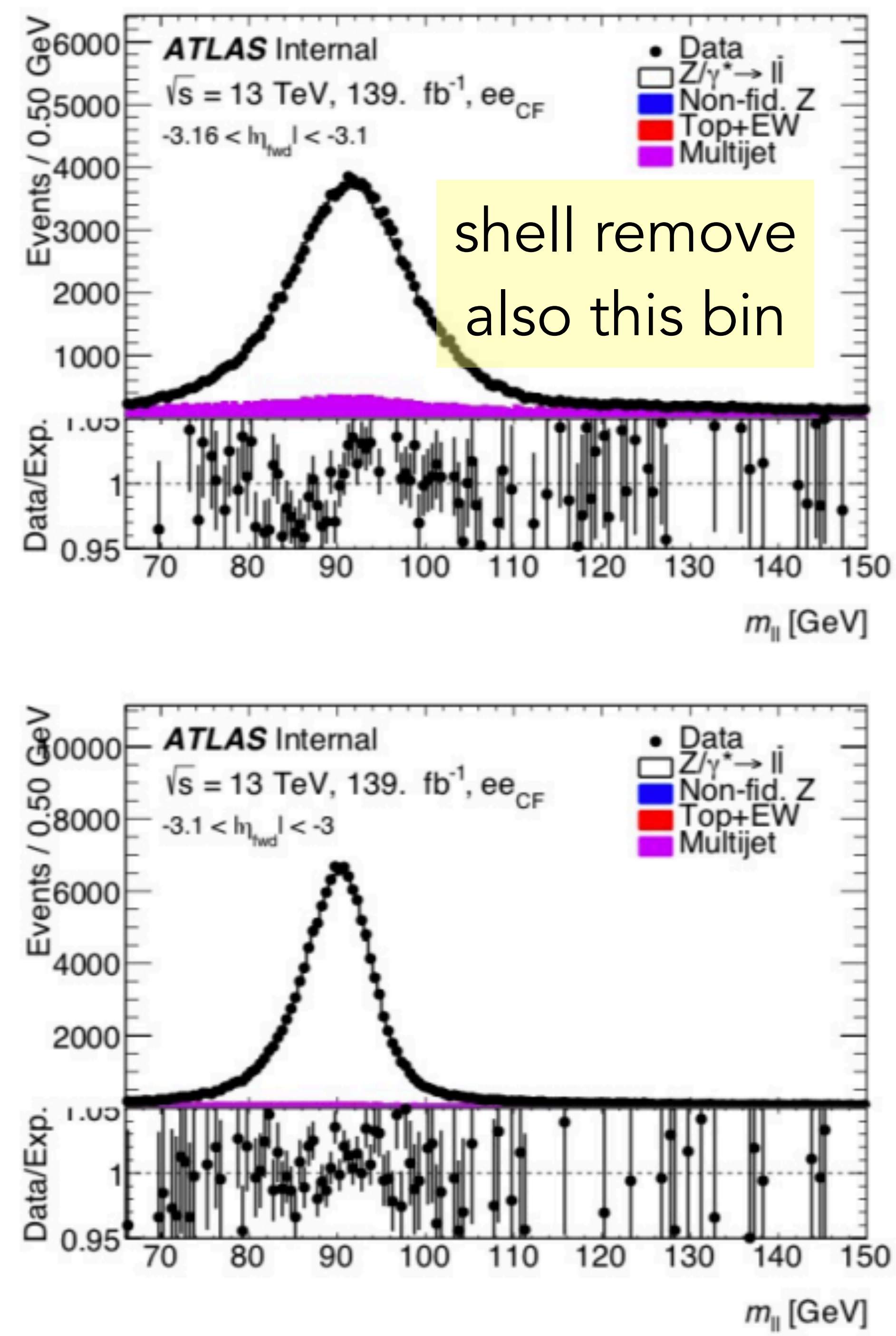


Forward Calorimeter

- $\eta \in [2.5, 4.9]$. No tracker here. ($\eta \in [3.16, 3.35]$ is crack region.)
- EMEC region: $\eta \in [2.5, 3.16]$.
- FCAL region: $\eta \in [3.35, 4.9]$.

3/23 Hanlin Xu Forward electrons ID and efficiency

CB



The transition region between the two calorimeters (3.16 < |η| < 3.35) is excluded from the study.

Crack definition

The sudden increase of material at $|\eta| \approx 3.2$, corresponding to the transition between the endcap calorimeters and the forward calorimeter, is mostly due to the cryostat that acts also as a support structure. (https://arxiv.org/pdf/1404.2240.pdf)

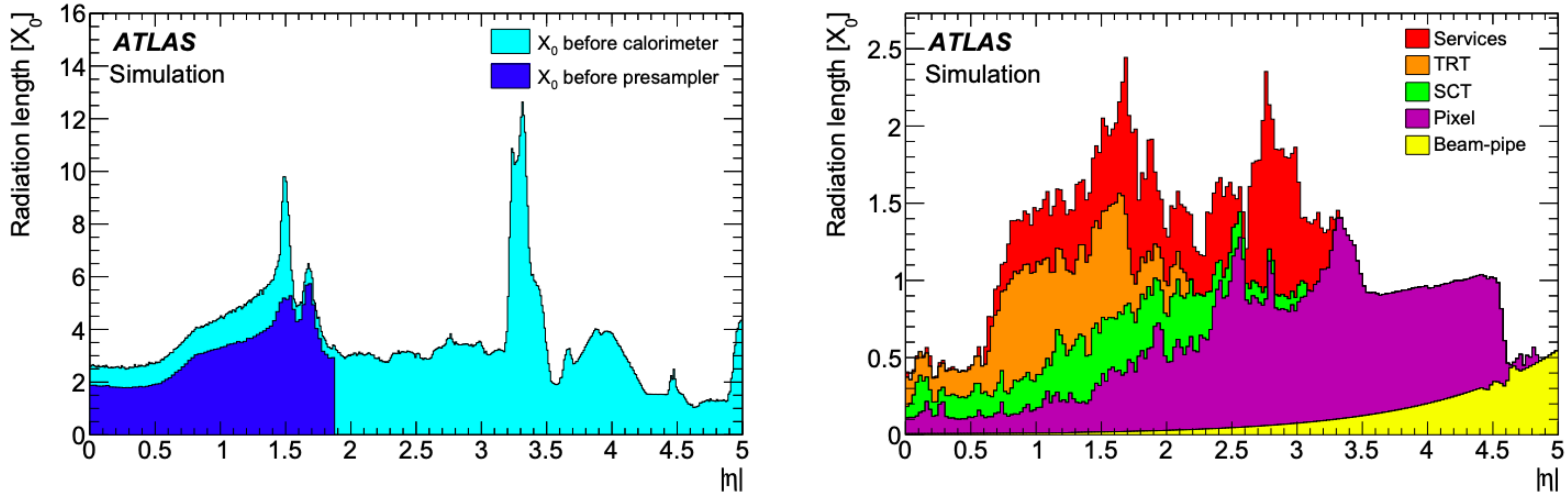
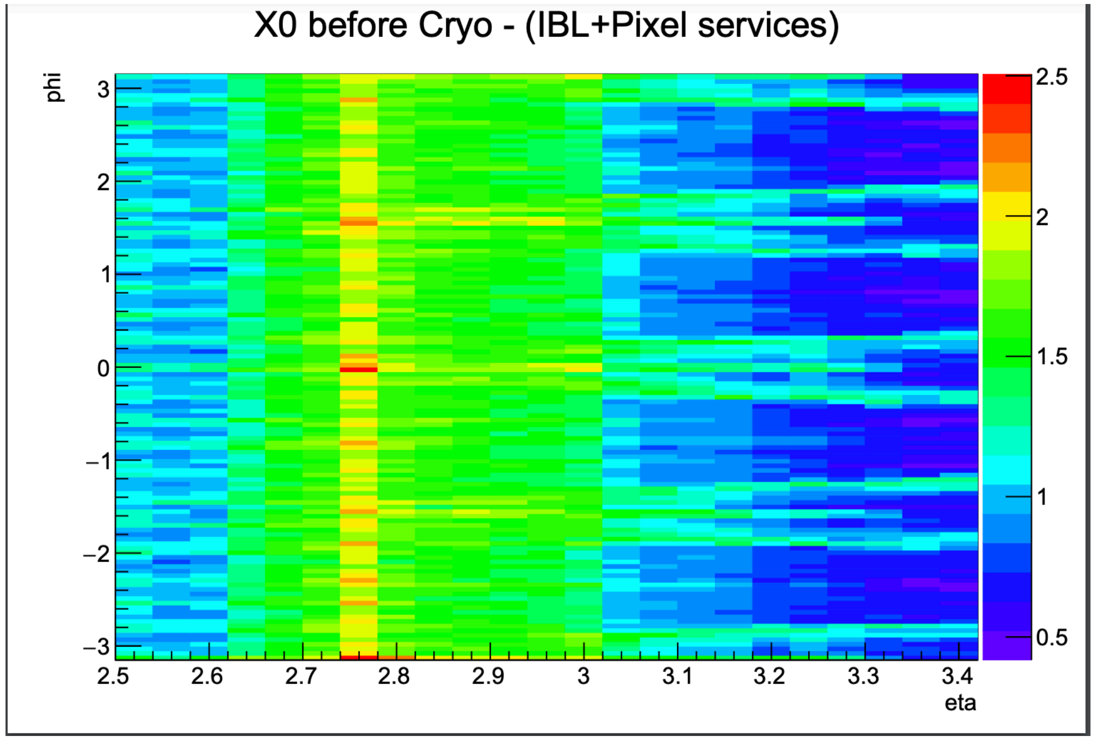
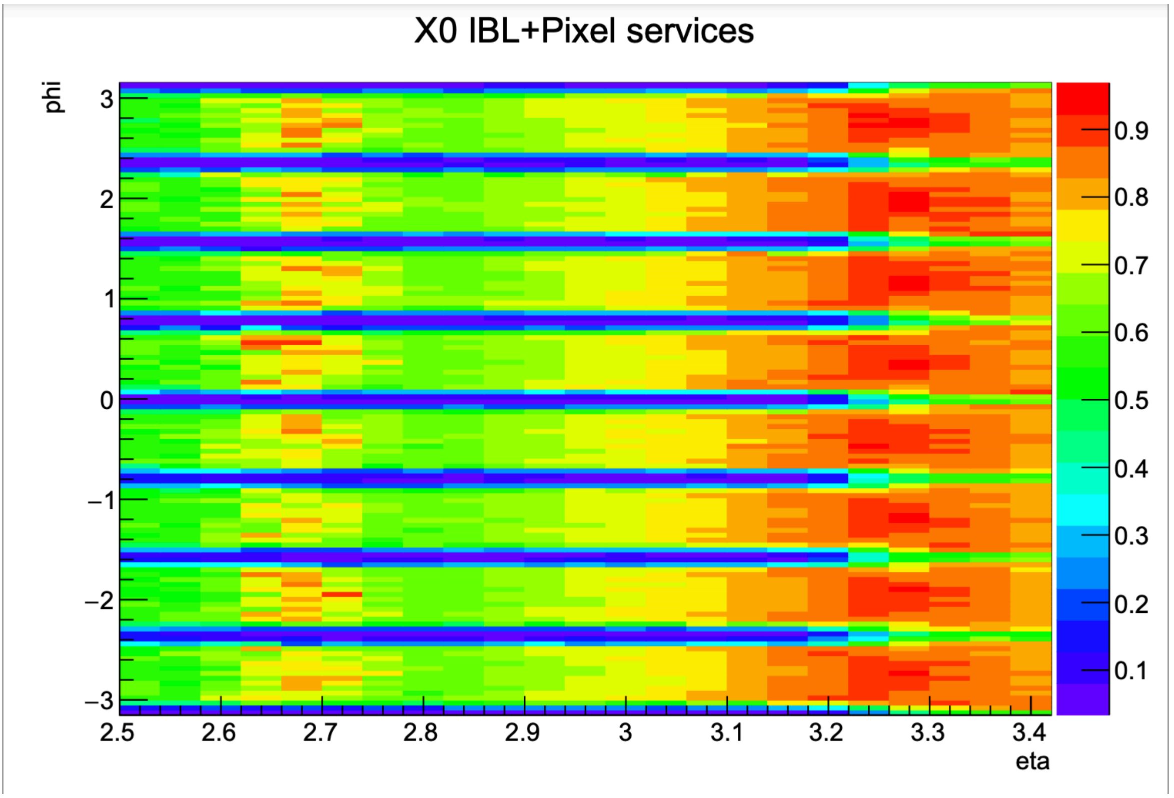


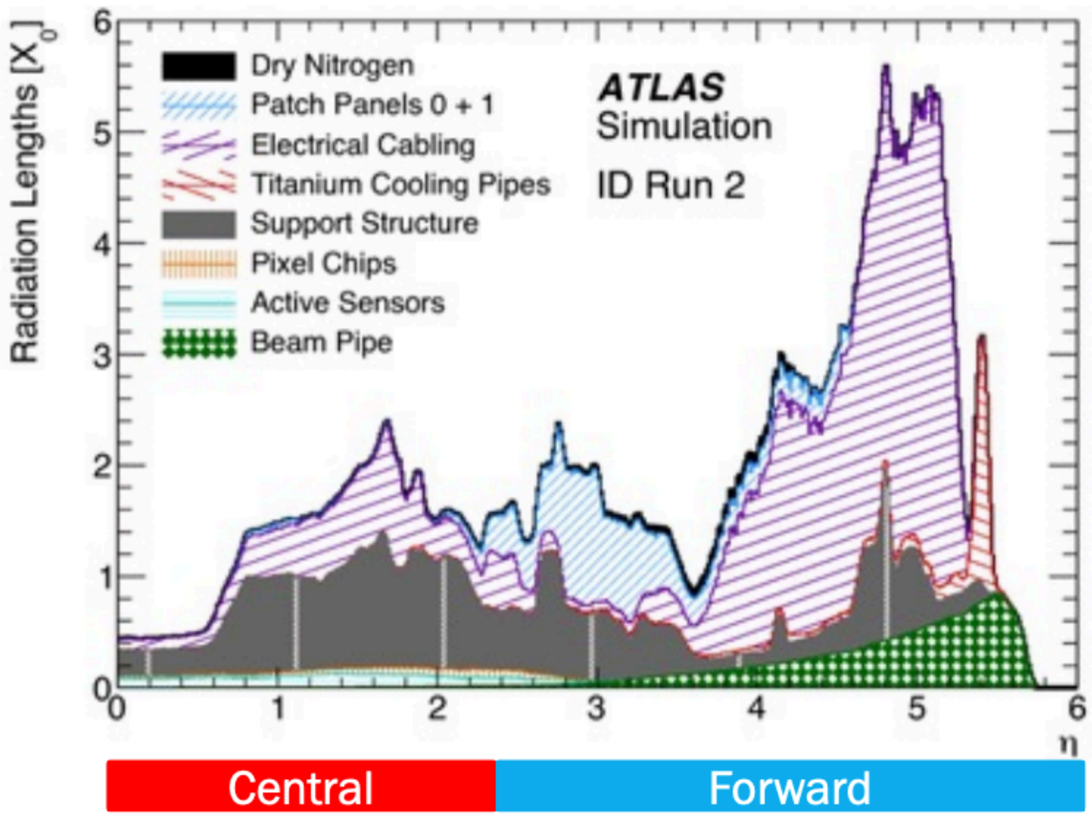
Figure 1: Amount of material, in units of radiation length X_0, traversed by a particle as a function of $|\eta|$: material in front of the presampler detector and the EM accordion calorimeter (left), and material up to the ID boundaries (right). The contributions of the different detector elements, including the services and thermal enclosures are shown separately by filled colour areas.

I think the 3.16 is used to match the sudden increase of the material the real transition starts at 3.1 but the material start to increase after the 3.16 +1cell ~

Dead material in Run3

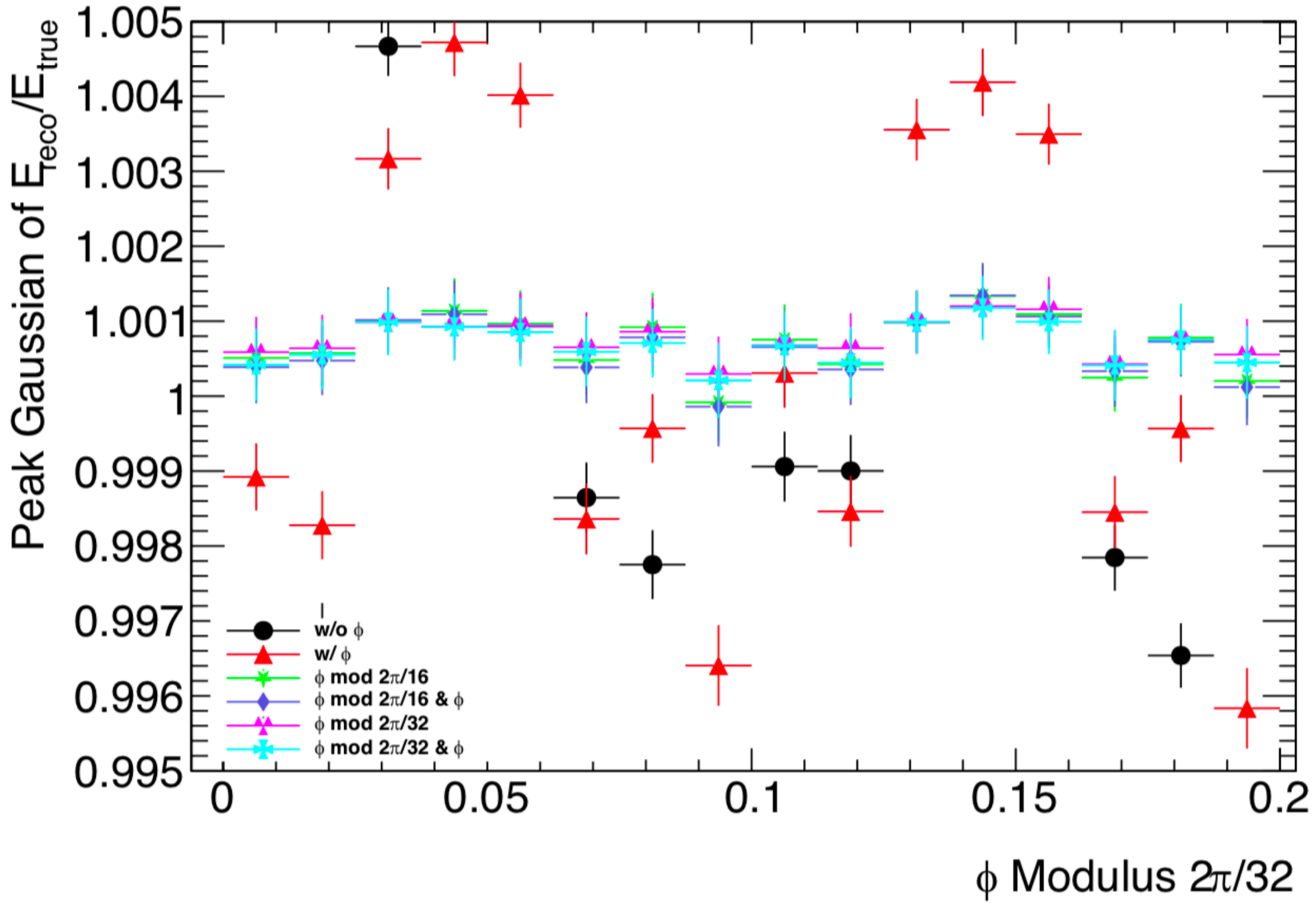






Passive material in ATLAS

follow up of the phi mod choosen for the training



For comparison, the FCAL granularity is approximately $\Delta\eta\times\Delta\phi = 0.15\times0.15(0.3\times0.3)$ at $\eta = 3.5(4.5)$.

Table 1: The read-out granularity of the ATLAS calorimeter system [1], given in terms of $\Delta\eta\times\Delta\phi$ with the exception of the forward calorimeters, where it is given in linear measures $\Delta x\times\Delta y$, due to the non-pointing read-out geometry of the FCAL. For comparison, the FCAL granularity is approximately $\Delta\eta\times\Delta\phi = 0.15\times0.15(0.3\times0.3)$ at $\eta = 3.5(4.5)$. The total number of read-out cells, including both ends of the calorimeter system, with (without) pre-samplers is 187 652 (178 308).

Calorimeter	Module	Sampling (S_{calo})	N_{cells}	η-coverage	$\Delta\eta\times\Delta\phi$
Electromagnetic calorimeters	EMB		109 568	$\|\eta\| < 1.52$	
		PreSamplerB	7 808	$\|\eta\| < 1.52$	$0.025\times\pi/32$
		EMB1		$\|\eta\| < 1.4$	$0.025/8\times\pi/32$
				$1.4 < \|\eta\| < 1.475$	$0.025\times\pi/128$
		EMB2		$\|\eta\| < 1.4$	$0.025\times\pi/128$
				$1.4 < \|\eta\| < 1.475$	$0.075\times\pi/128$
		EMB3		$\|\eta\| < 1.35$	$0.050\times\pi/128$
	EMEC		63 744	$1.375 < \|\eta\| < 3.2$	
		PreSamplerE	1 536	$1.5 < \|\eta\| < 1.8$	$0.025\times\pi/32$
		EME1		$1.375 < \|\eta\| < 1.425$	$0.050\times\pi/32$
				$1.425 < \|\eta\| < 1.5$	$0.025\times\pi/32$
				$1.5 < \|\eta\| < 1.8$	$0.025/8\times\pi/32$
				$1.8 < \|\eta\| < 2.0$	$0.025/6\times\pi/32$
				$2.0 < \|\eta\| < 2.4$	$0.025/4\times\pi/32$
				$2.4 < \|\eta\| < 2.5$	$0.025\times\pi/32$
				$2.5 < \|\eta\| < 3.2$	$0.1\times\pi/32$
		EME2		$1.375 < \|\eta\| < 1.425$	$0.050\times\pi/128$
				$1.425 < \|\eta\| < 2.5$	$0.025\times\pi/128$
				$2.5 < \|\eta\| < 3.2$	$0.1\times\pi/128$
		EME3		$1.5 < \|\eta\| < 2.5$	$0.050\times\pi/128$
Hadronic calorimeters	Tile (barrel)		2 880	$\|\eta\| < 1$	
		TileBar0/1			$0.1\times\pi/32$
		TileBar2			$0.2\times\pi/32$
	Tile (extended barrel)		2 304	$0.8 < \|\eta\| < 1.7$	
		TileExt0/1			$0.1\times\pi/32$
		TileExt2			$0.2\times\pi/32$
	HEC		5 632	$1.5 < \|\eta\| < 3.2$	
		HEC0/1/2/3		$1.5 < \|\eta\| < 2.5$	$0.1\times\pi/32$
				$2.5 < \|\eta\| < 3.2$	$0.2\times\pi/16$
Forward calorimeters	FCAL		3 524	$3.1 < \|\eta\| < 4.9$	$\Delta x\times\Delta y$
		FCAL0		$3.1 < \|\eta\| < 3.15$	1.5 cm × 1.3 cm
				$3.15 < \|\eta\| < 4.3$	3.0 cm × 2.6 cm
				$4.3 < \|\eta\| < 4.83$	1.5 cm × 1.3 cm
		FCAL1		$3.2 < \|\eta\| < 3.24$	1.7 cm × 2.1 cm
				$3.24 < \|\eta\| < 4.5$	3.3 cm × 4.2 cm
				[redacted]	1.7 cm × 2.1 cm

https://arxiv.org/pdf/1603.02934.pdf

simplified geometry ATLAS calorimeter