Presampler layer calibration

Journées de Rencontre des Jeunes Chercheurs 2017
27/11/2017

Ahmed Tarek

LPNHE Paris · USPC Université Sorbonne Paris Cité · Université Paris Diderot Paris 7 · ATLAS Experiment

Outline

- Calorimeters : *A crash course*
- The ATLAS experiment
- Overview of EM calorimeter
- The ATLAS electron/photon calibration
  - The presampler scale recipe
    - Upstream material corrections $A(\eta)$
    - PS/Accordion material effects $b_{1/2}(\eta)$
    - PS scale stability
  - Conclusions

Calorimeters : a crash course

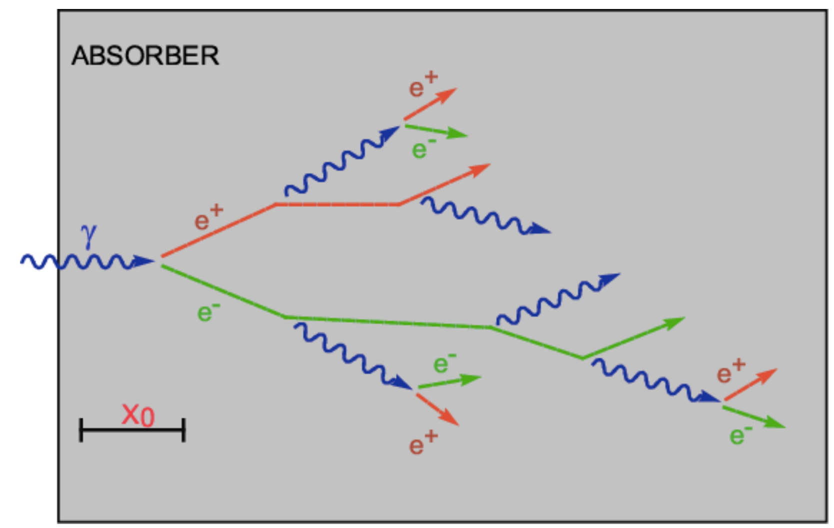
Calorimeters

- Common detector in particle/nuclear physics where the particles are fully absorbed by the detector (*destructive*)
- Particles deposit energy in various ways : heat, scintillation, Cherenkov radiation ..
- "Detection" is the conversion the incident particle energy to a response in the detector
- Location of energy deposit is used to "track" neutral particles

Electromagnetic calorimeter

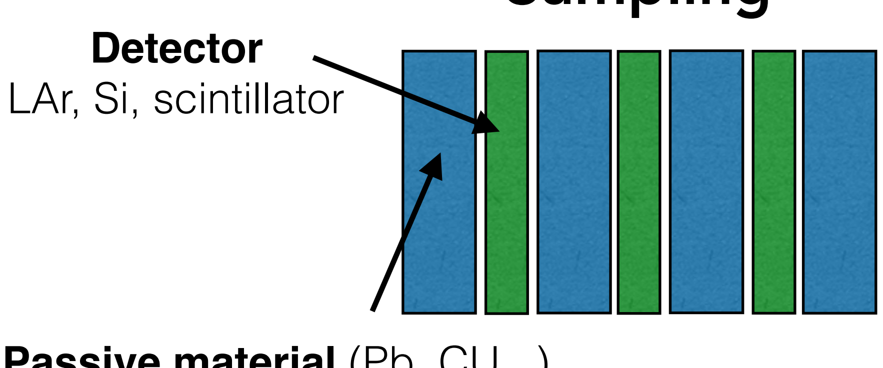
- Dominant process at high energies : pair production, bremsstrahlung
- Radiation length X_0 : when the energy of incident particle reduces by 1/e

a simple shower development model

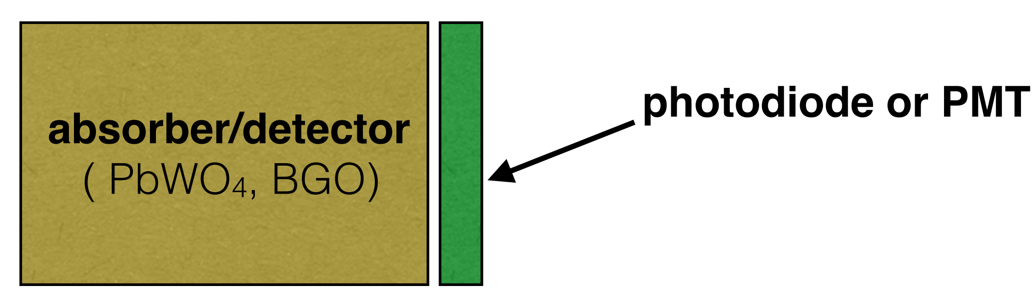


- Two main designs :

Sampling

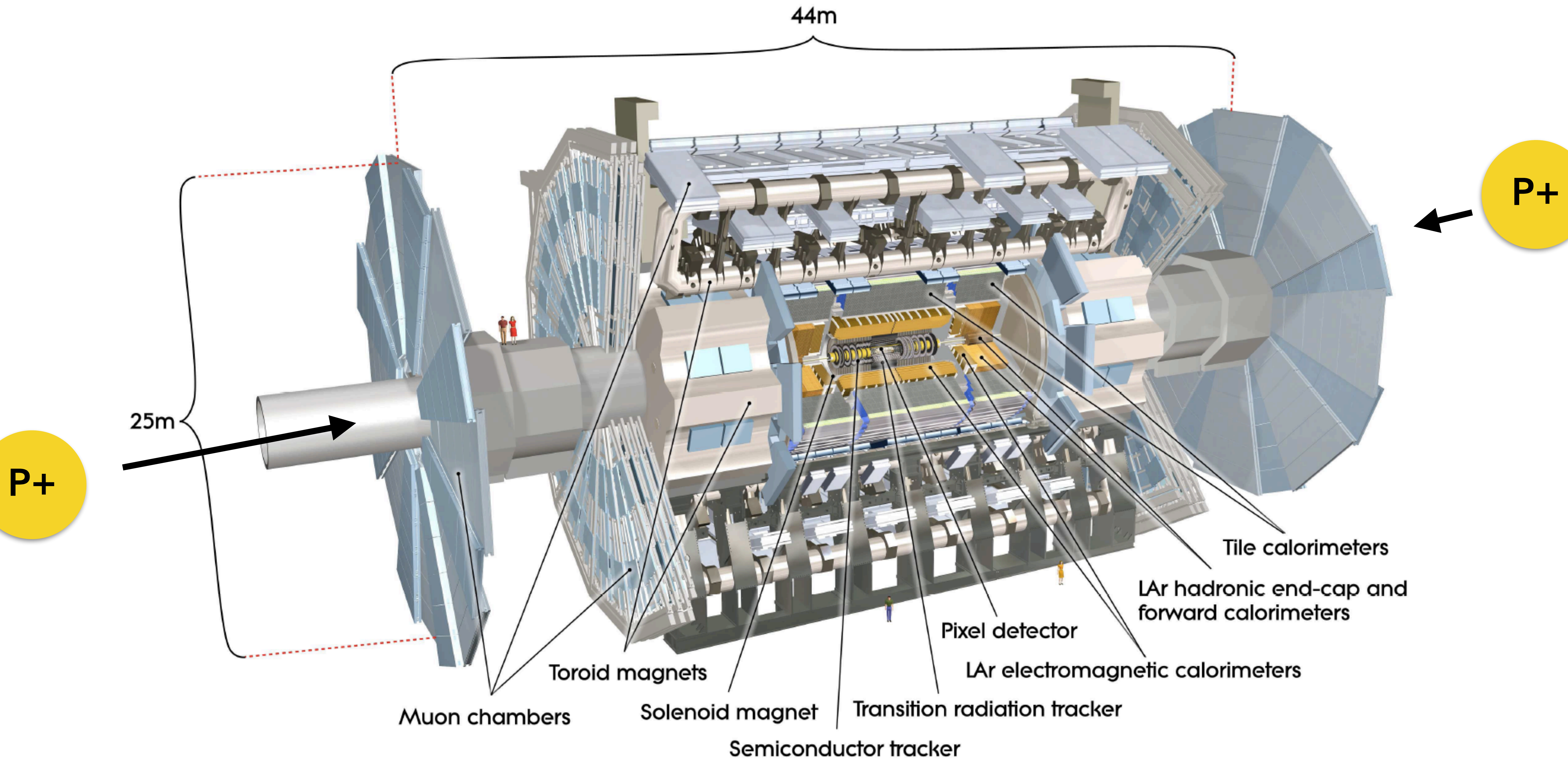


Homogenous

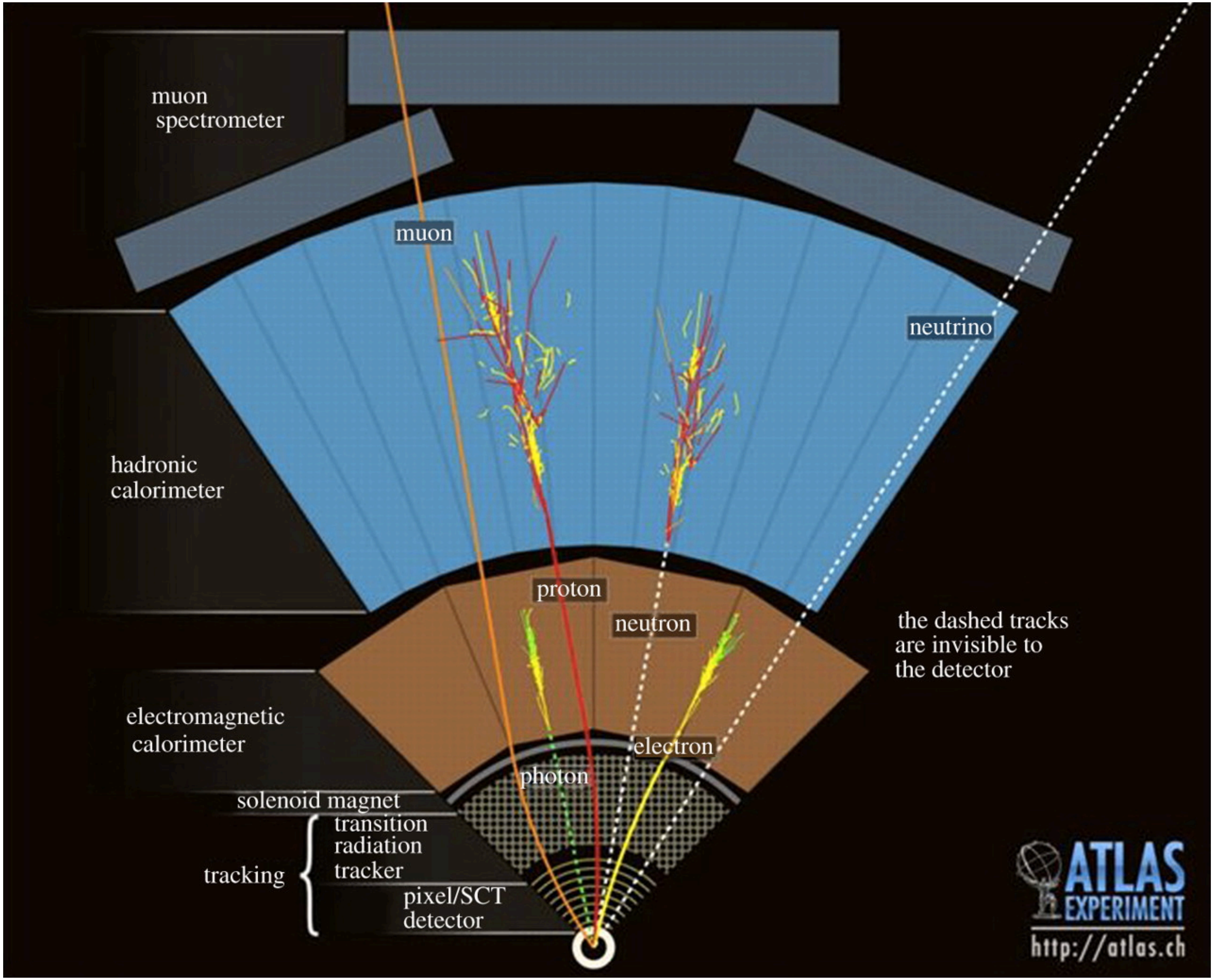


ATLAS

- A Toroidal Lhc ApparatuS
- One of two general purpose detectors at the Large Hadron Collider in CERN
- The biggest LHC experiment with ~ 3000 physicists



ATLAS

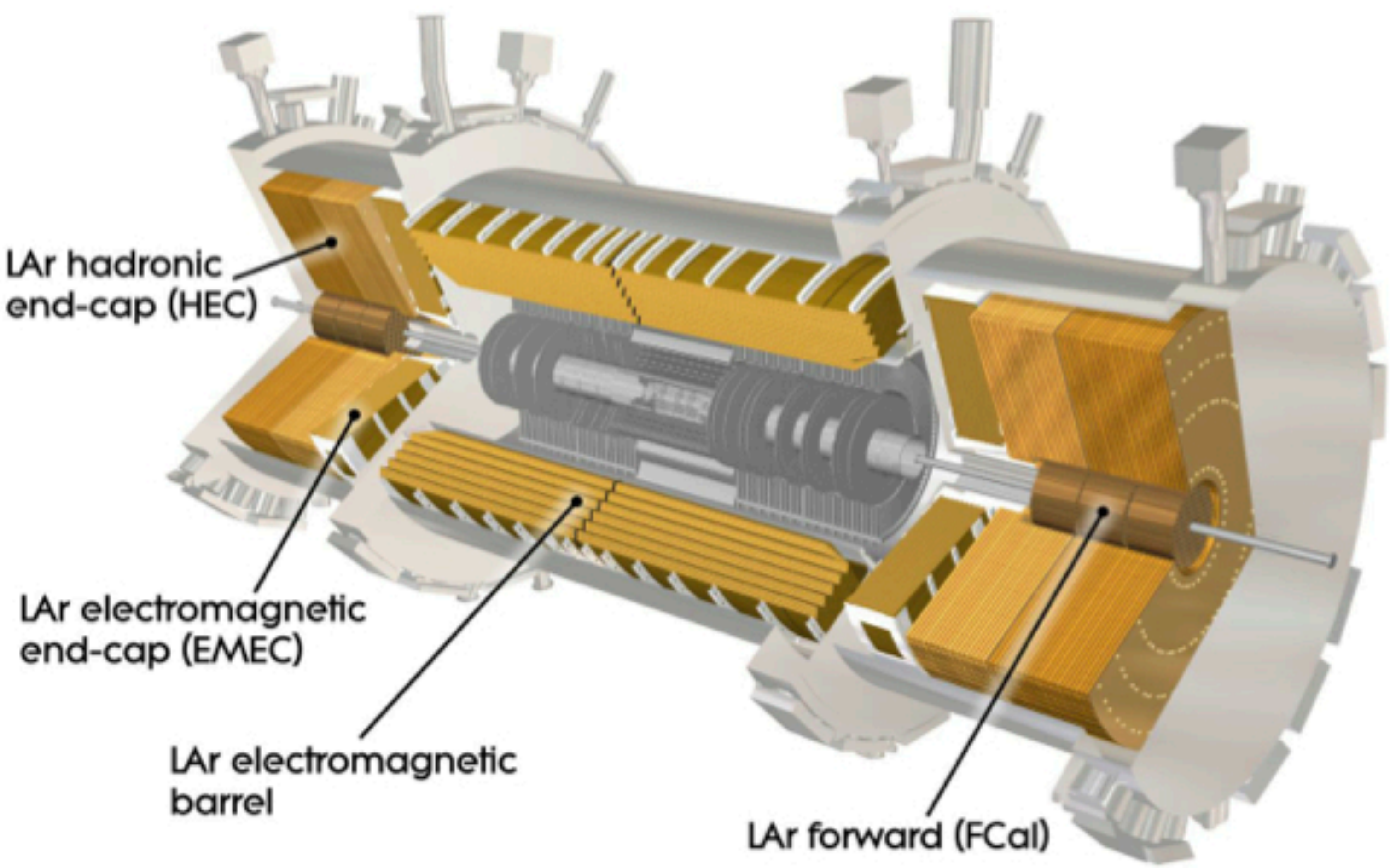


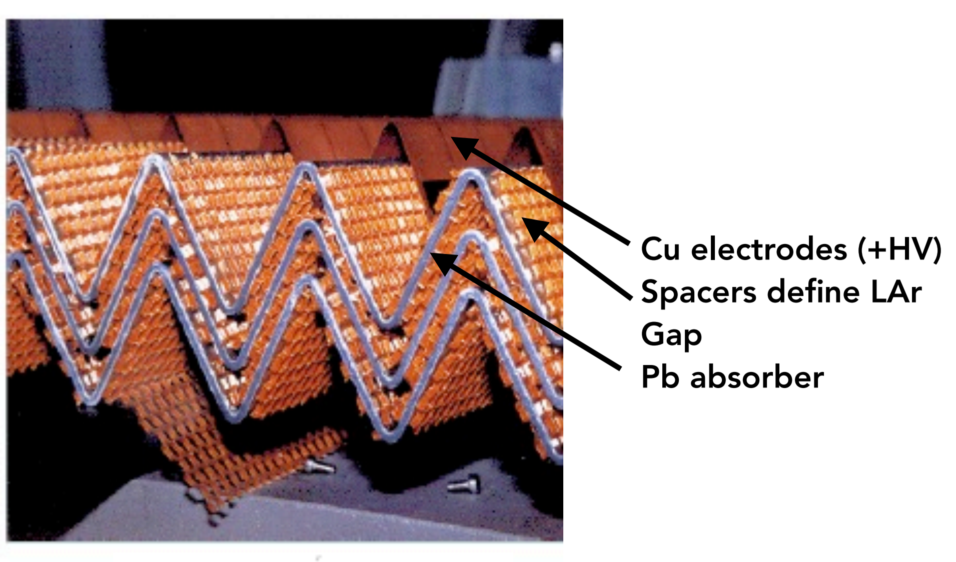
muon spectrometer
muon
hadronic calorimeter
neutrino
proton
neutron
the dashed tracks are invisible to the detector
electromagnetic calorimeter
electron
photon
solenoid magnet
transition radiation tracker
tracking
pixel/SCT detector
ATLAS EXPERIMENT
http://atlas.ch

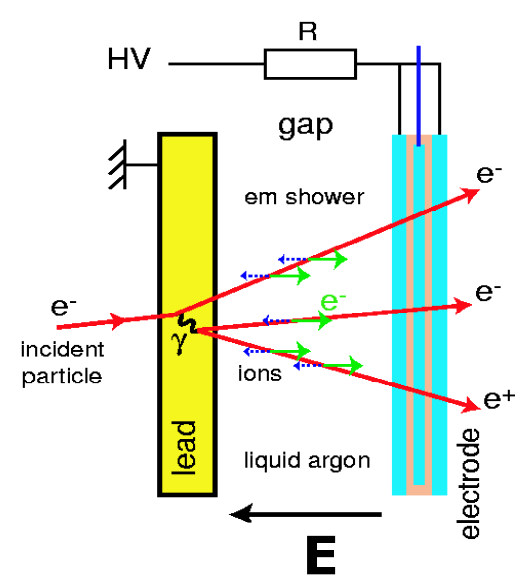
ATLAS electromagnetic calorimeter

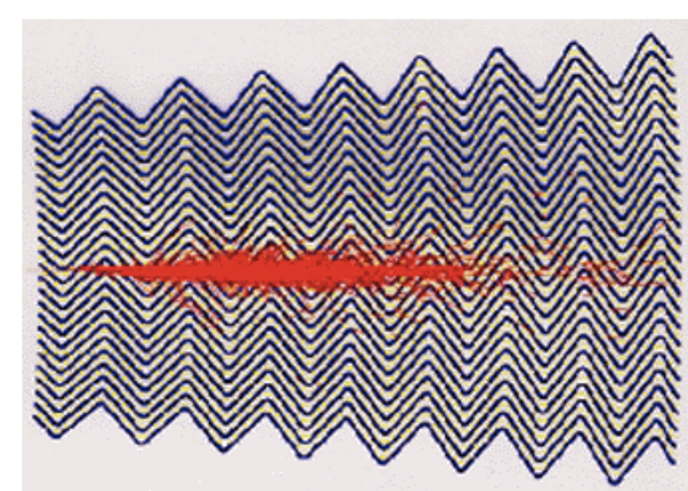
Lead liquid Aragon (LAr) sampling calorimeter with accordion geometry

- **Divided into two regions**
  - Barrel (EMEB) $0<|\eta|<1.475$
  - Endcap (EMEC) $1.375<|\eta|<3.2$
  - HV system provides (1 kV/mm) to ionise electrons



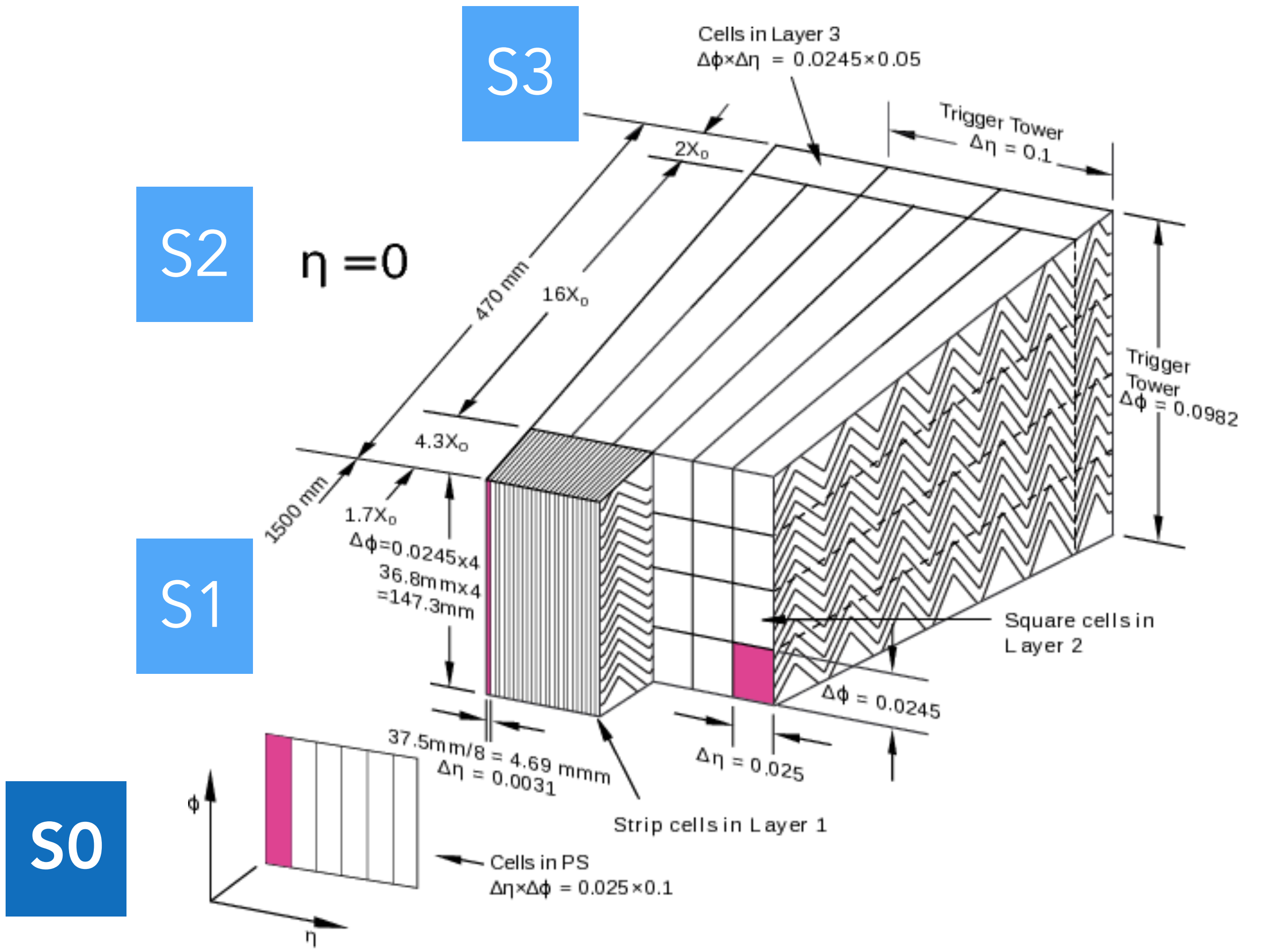






ATLAS electromagnetic calorimeter -2

- **S0 (Presampler)**
- S1 (Strips) : γ/π^0 separation
- S2 (Middle) : Main energy deposit
- S3 (Back) : High energy showers



- **The Presampler (PS)** recovers part of the energy for particles that started showering before reaching the calorimeter
  - Does not contain any absorber material
  - Covers |η| <1.8
    - 0<|η|<1.52 Barrel, 1.5<|η|<1.8 Endcaps

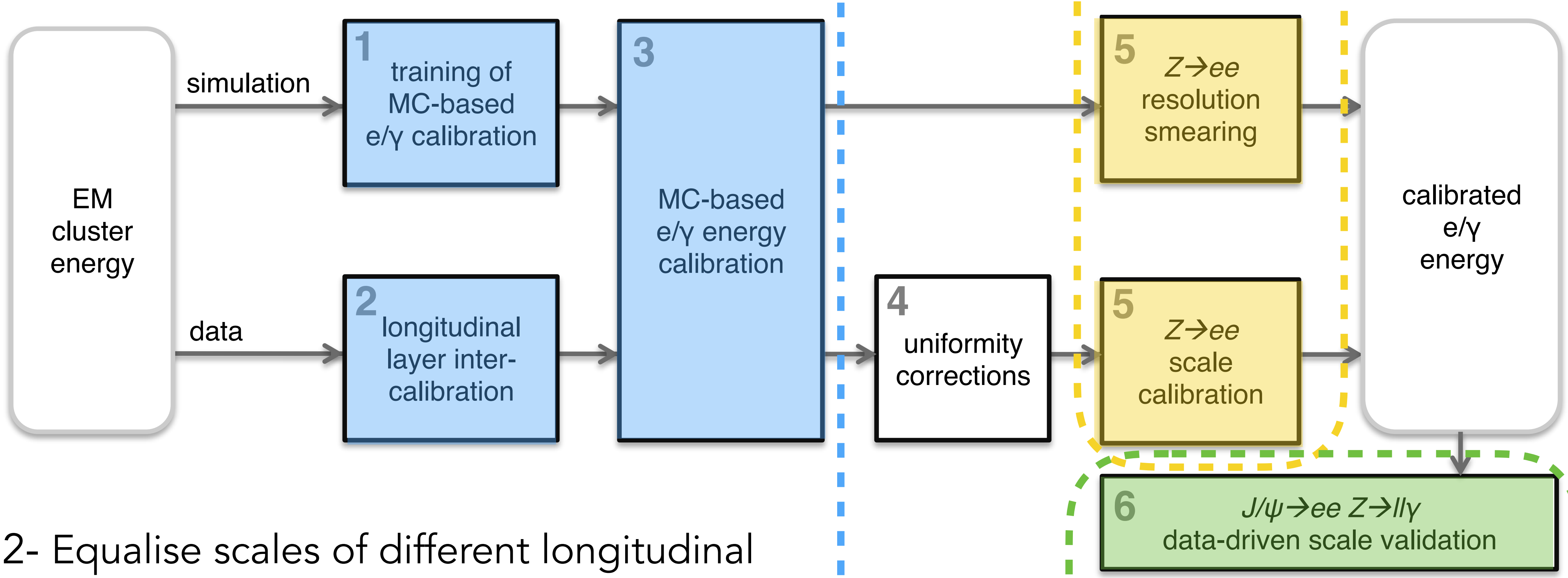
Calibration scheme

MC based calibration

1- calibrate EM clusters to original electron/ photon energy using multivariate analysis

Data based calibration

photon/electron energy scale adjusted to EM scale Z->ee events



2- Equalise scales of different longitudinal layers between data/MC

- Intercalibration of the first and Second layer and the **presampler**

3- Apply MC response (from MVA) on data/ MC clusters

Validation

Validate method with election candidate at low energy

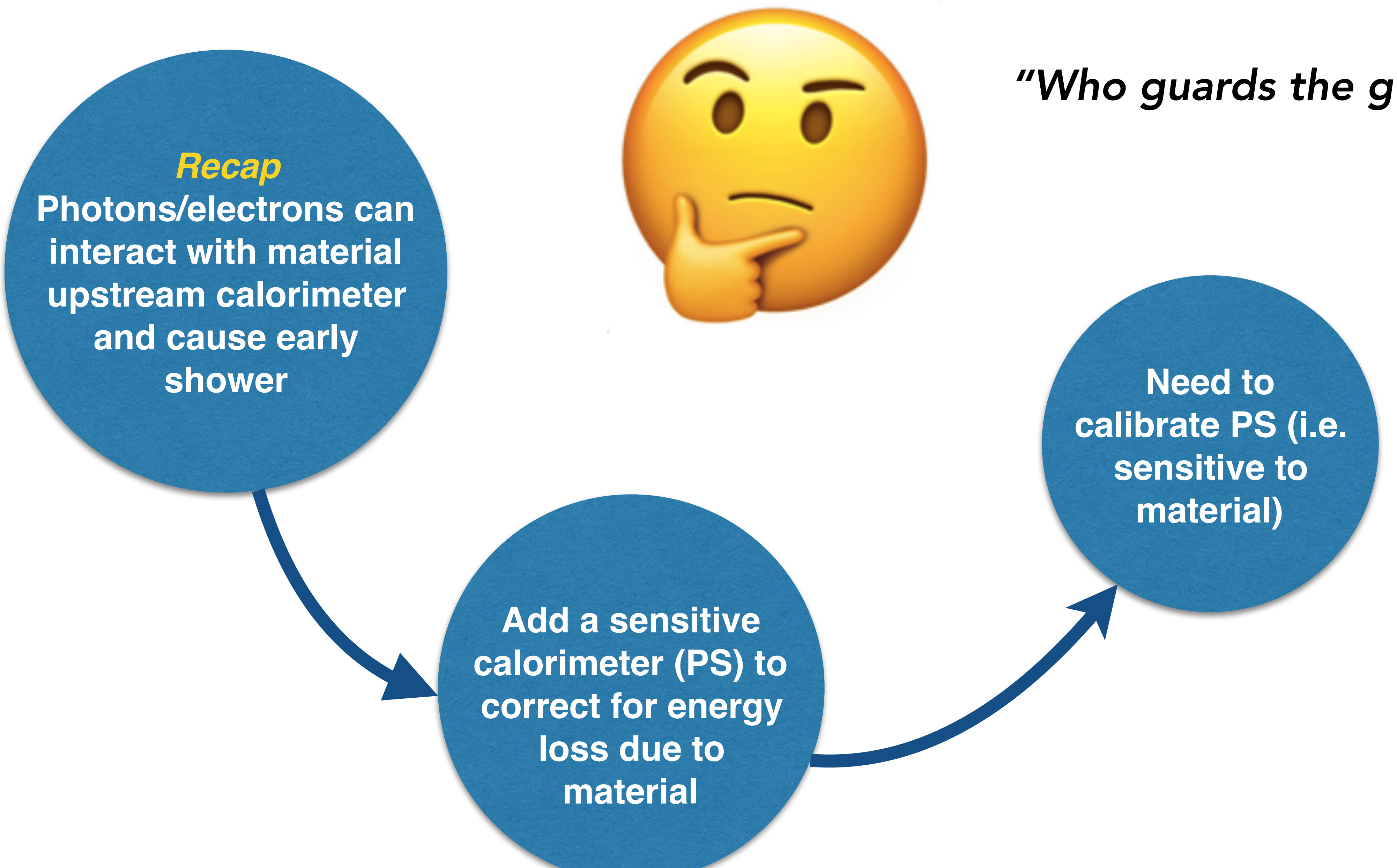
PS scale determination

Introduction

Presampler scale: The ratio of the presampler energy between data and simulation

- Energy deposited in the **PS is very sensitive to the presence of extra material** ahead of the calorimeter
- Different material between data and simulation will bias the scale estimation

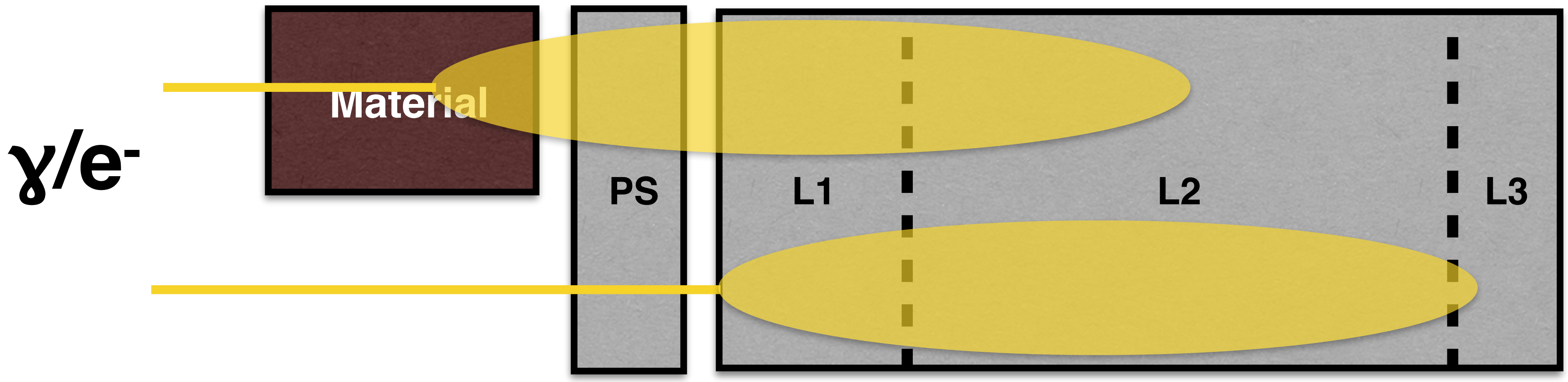
"Who guards the guards ?"



PS scale determination
Challenges

Muons are insensitive to upstream material but the energy deposit is too low in the PS (MIP)

⇒ **Scale is determined from electrons from Z decays.**

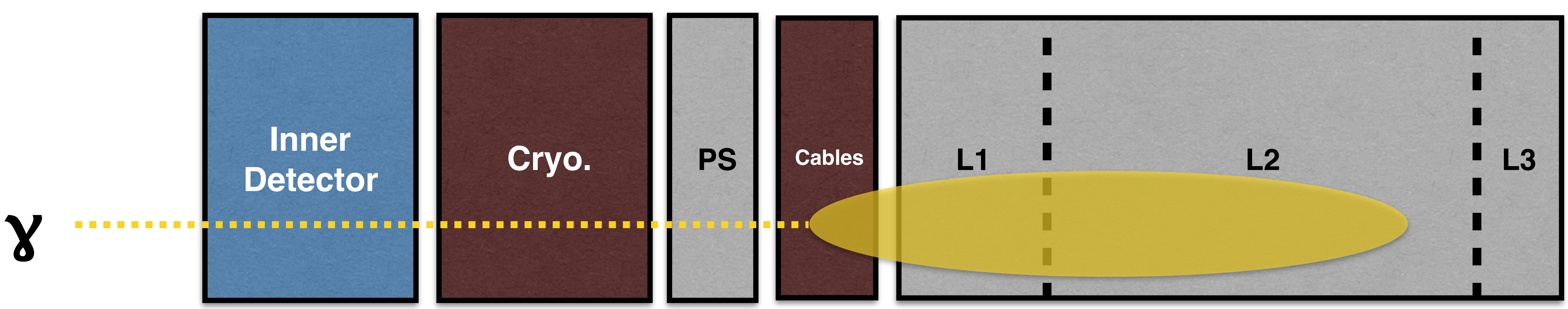


More Material → Early shower development → Larger energy deposits in L1 compared to L2

Solution : Use information from the ratio first and second layers energies E_1/E_2 ($E_{1/2}$) !

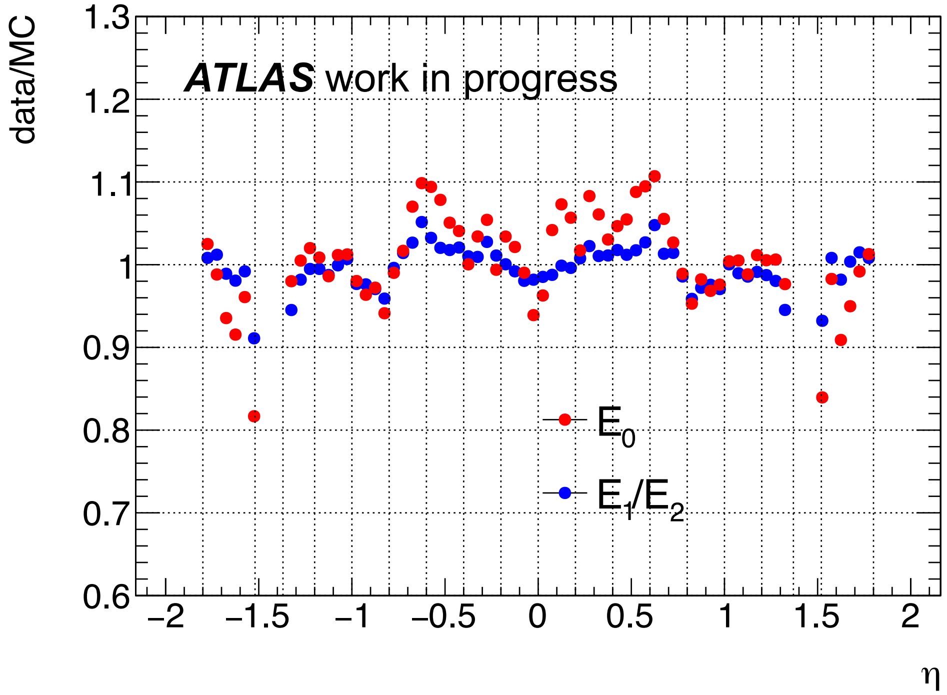
⚠ **There's also material (cables) between PS and L1**

Solution : Use unconverted photons with low PS activity to probe this region



Unconverted **Low E_0**

PS scale determination
Recipe



Proof of principle

E_0 and $E_{1/2}$ show similar patterns between data and simulation

PS scale

$$\alpha_{PS}(\eta) = \frac{E_0^{data}(\eta)}{E_0^{corr}(\eta)}$$

Corrected MC

where Material correction :

$$\frac{E_0^{corr}(\eta)}{E_0^{nom}(\eta)} = 1 + A(\eta)\left(\frac{E_{1/2}^{data}(\eta)}{E_{1/2}^{nom}(\eta)\, b_{1/2}(\eta)} - 1\right)$$

$A(\eta)$: E_0, $E_{1/2}$ Correlation slope

$b_{1/2}(\eta)$: Material after the PS correction

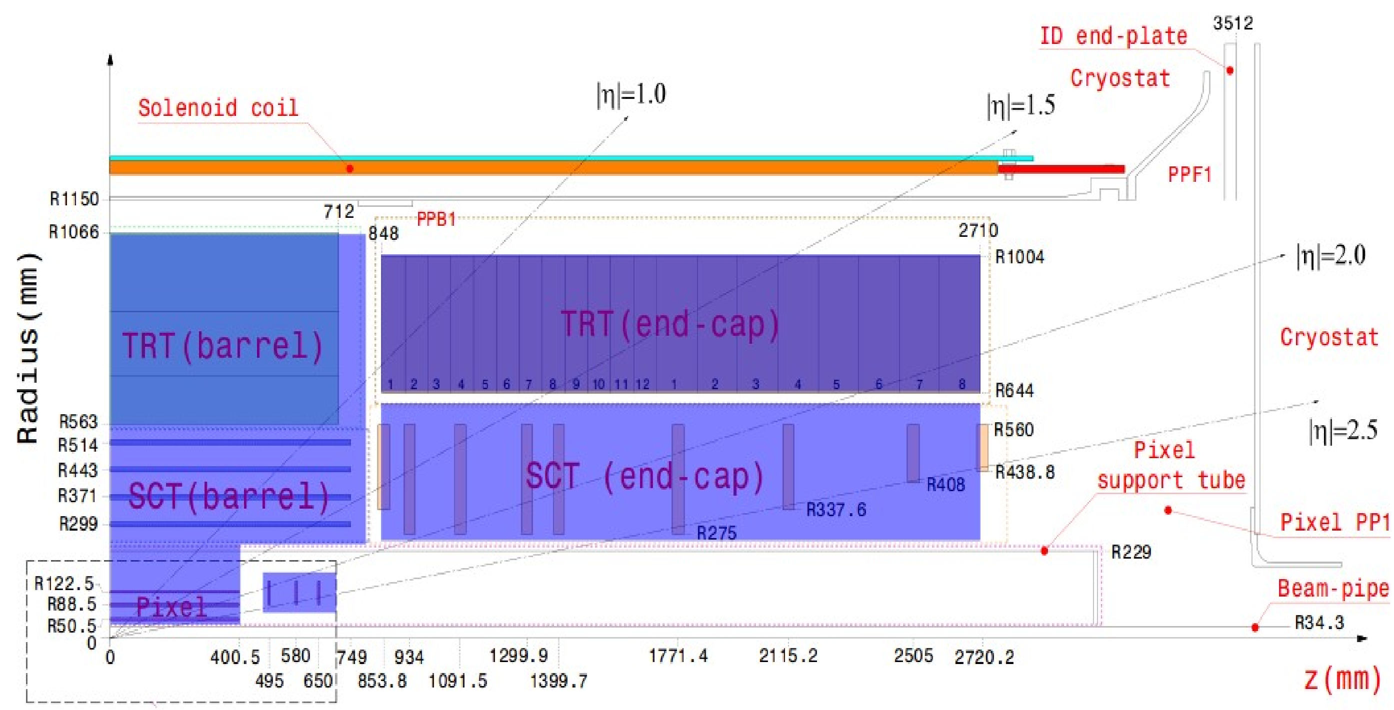
Upstream material correction $A(\eta)$

- $A(\eta)$ is the slope of the linear fit of the correlation between $E_{1/2}$ and E_0
- Estimated from geometry variations upstream the calorimeter

Config	ID	ID-EC	Pixel S	SCT S	SCT/TRT-EC	PS/S1-B	PS/S1-EC	Cryo 1	Calo-EC
A	5%	-	-	-	-	-	-	-	-
N	-	-	-	-	-	-	5%	-	-
C'+D'	-	-	10%	10%	-	-	-	-	-
E'+L'	-	-	-	-	7.5%	-	-	5%	-
F'+M+X	-	7.5%	-	-	-	5%	-	-	30%
G'	5%	7.5%	10%	7.5%	5%	5%	5%	5%	30%
IBL	Improved IBL geometry								
PP0	50% increase in IBL + pixel services								

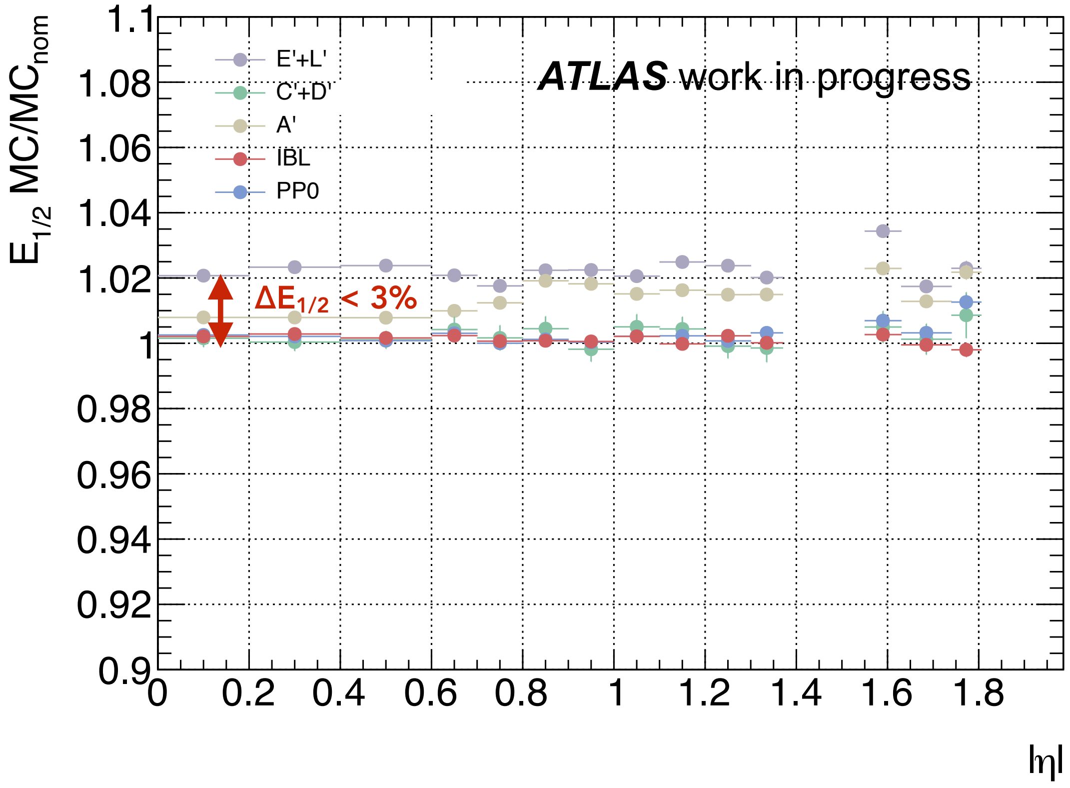
Samples with material after the PS (F'+M+X, G')

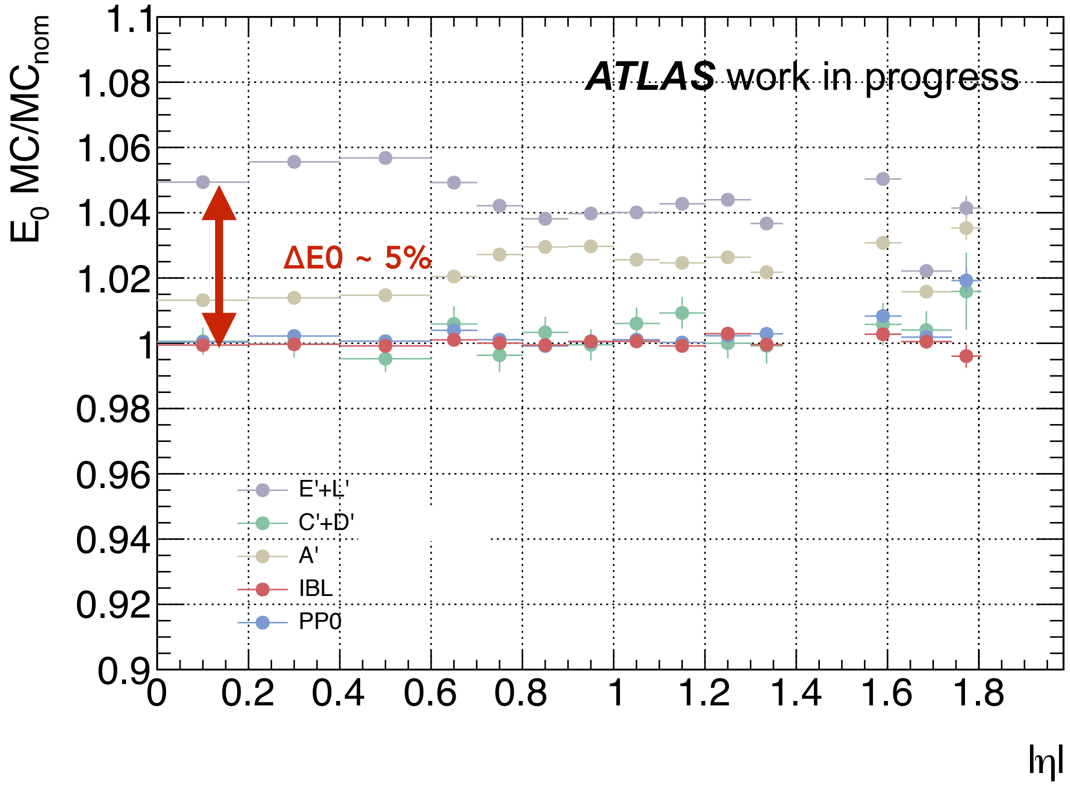
ex. **Config A** *MC15 geometry.* ***5%*** *ID materials scale*



Upstream material correction $A(\eta)$

- $A(\eta)$ is the slope of the linear fit of the correlation between $E_{1/2}$ and E_0
- Estimated from geometry variations upstream the calorimeter

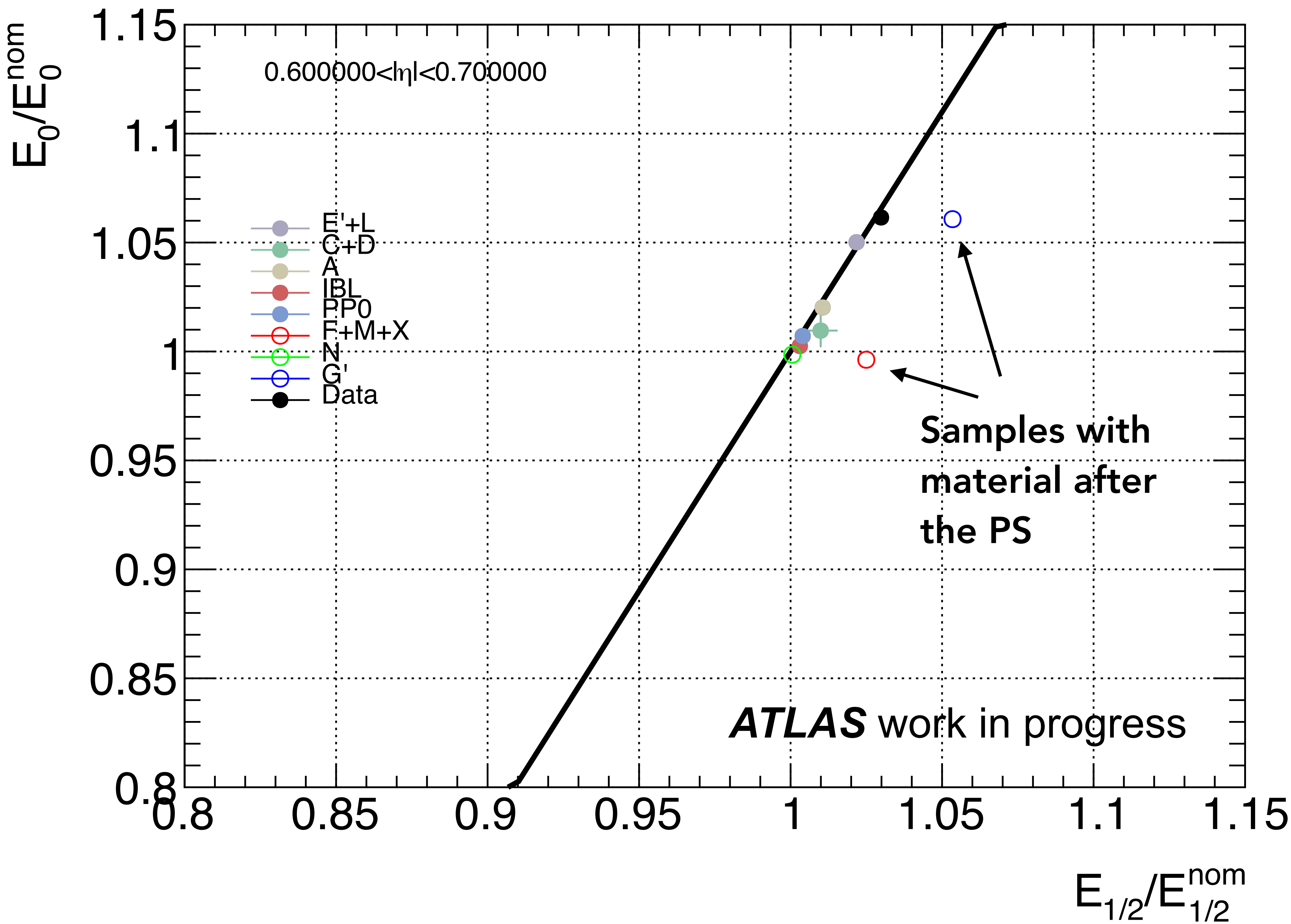




Upstream material correction $A(\eta)$

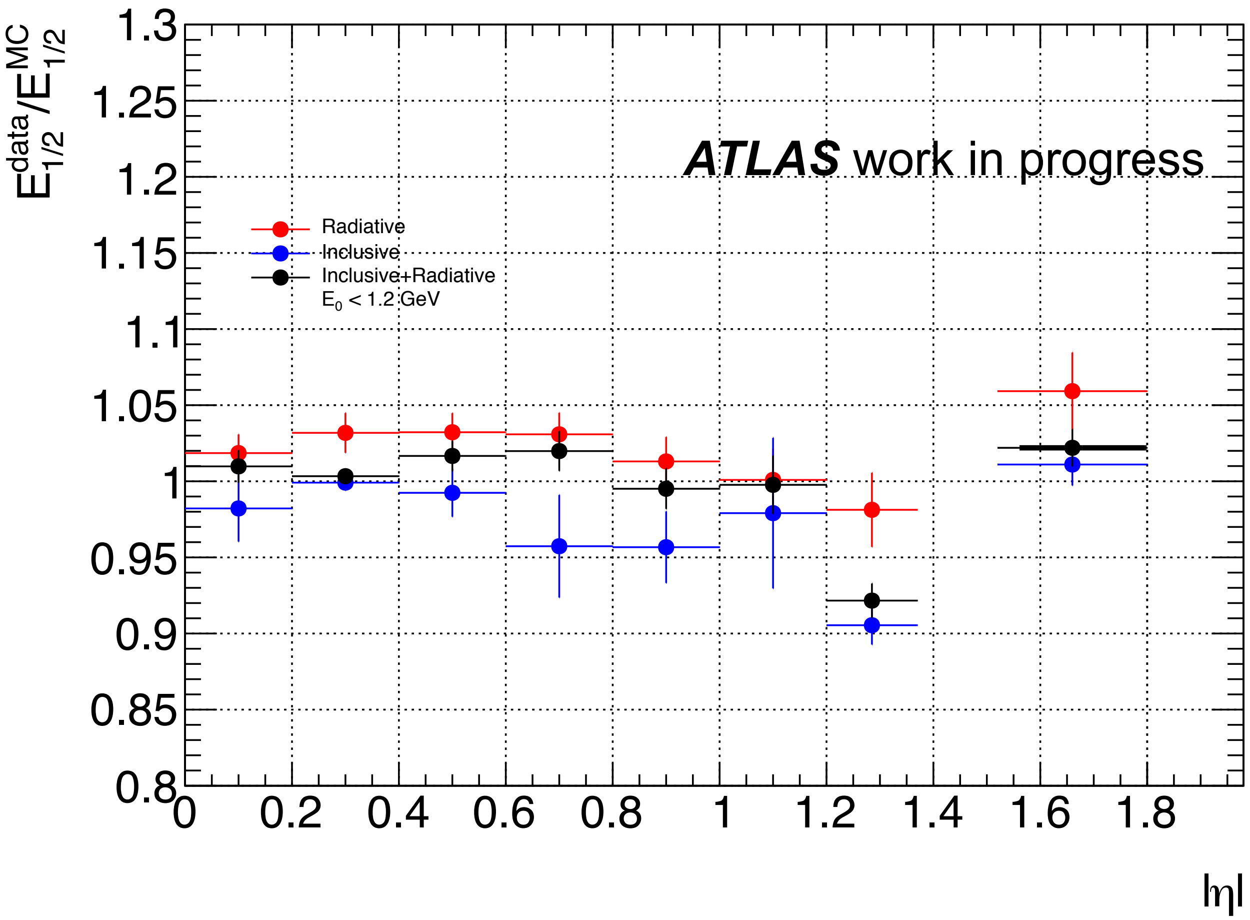
$E_{1/2}$, E_0 correlation plot

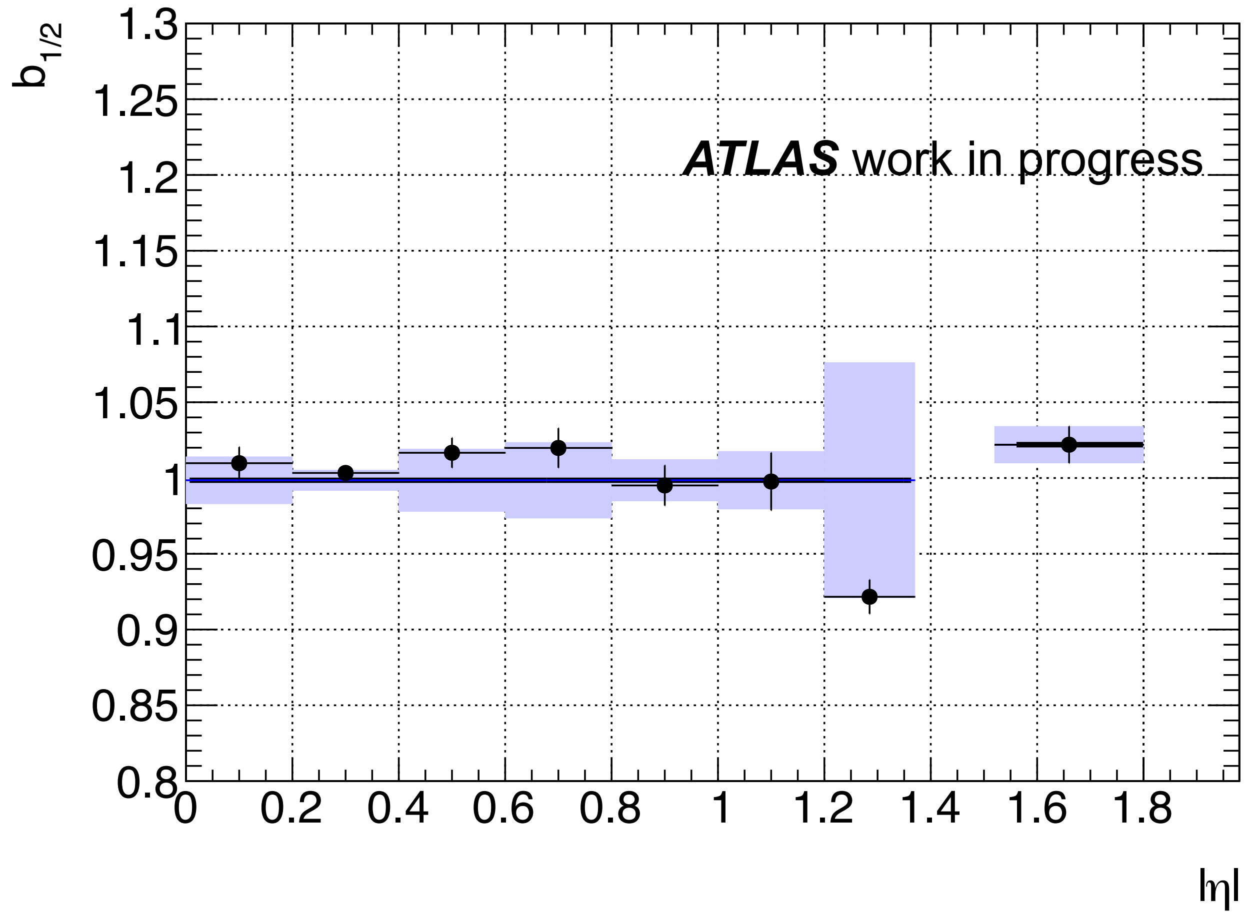
- *Example of correlation plots :*



PS/Accordion material effects $b_{1/2}(\eta)$

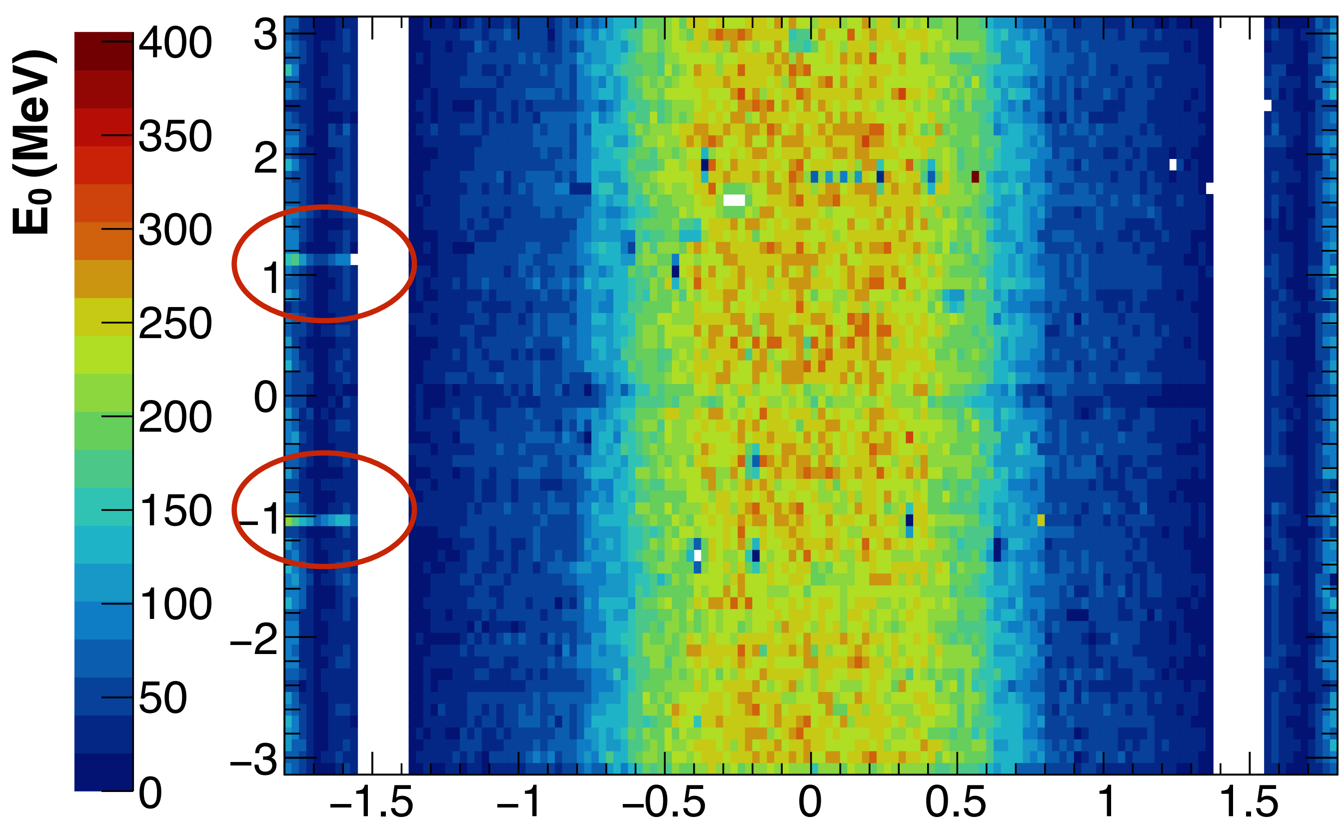
- **Use photo samples from different sources (different p_T ranges)**
  - Hight p_T : Single photon samples
  - Low p_T : Radiative-Z samples
- **Select only unconverted photons and veto events E_0 < 1.2 GeV**

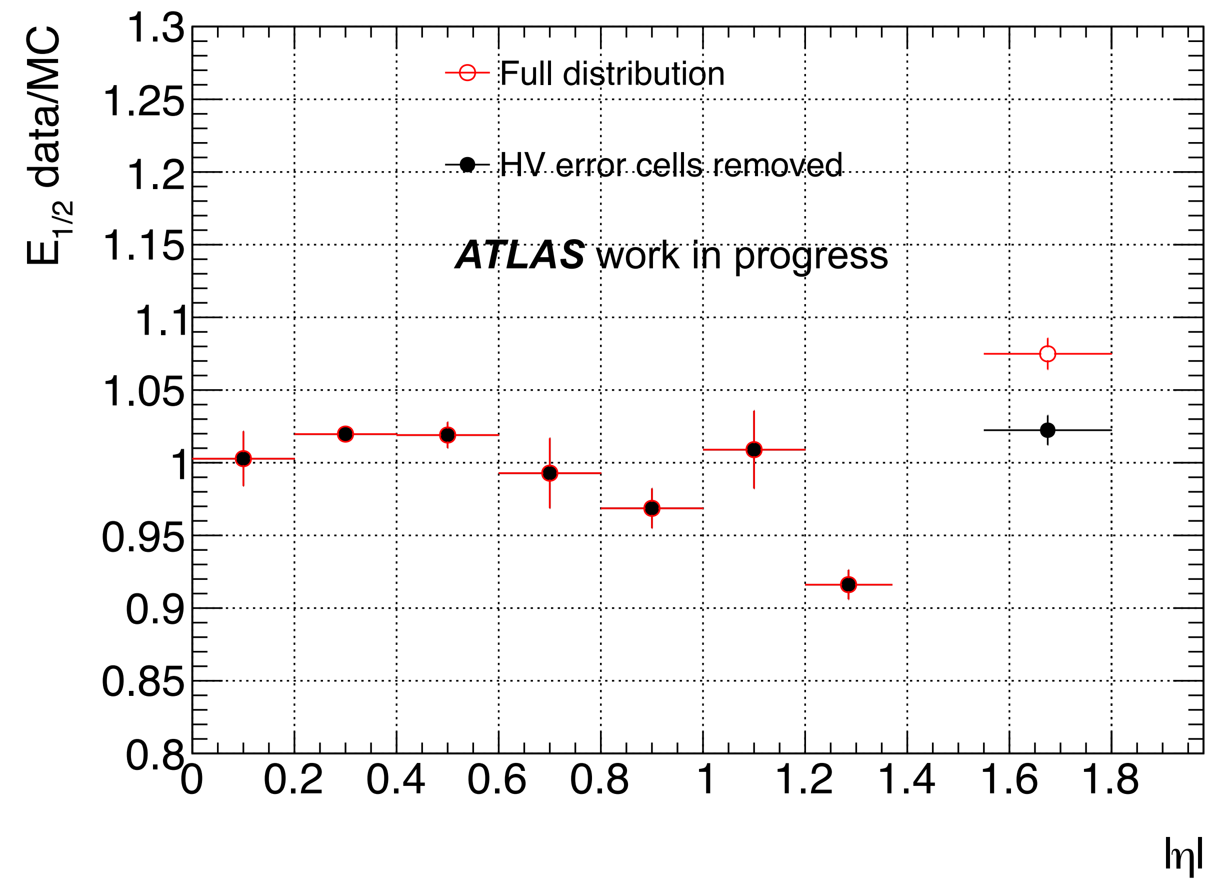




HV Investigation

- Unexpected discrepancy observed with the simulation when PS veto is applied
  - No extra material is added in the region PS-strips





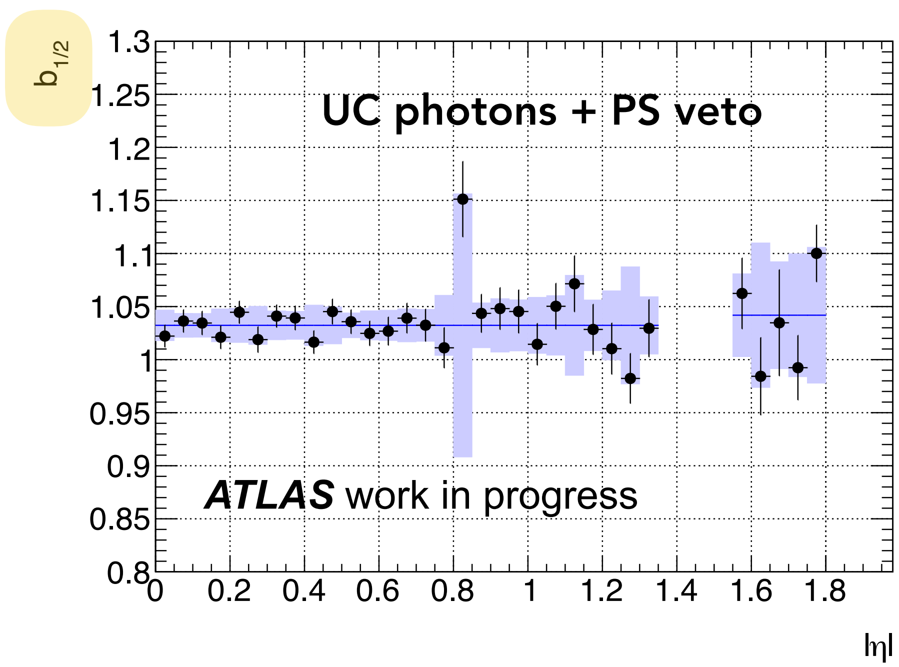
- **Discrepancy in HV mapping between data and simulation found !**
  - Real situation : one HV line power two gaps of one cell
  - Simulation : one HV line power one gap of two cells (similar to the rest of the calorimeter)

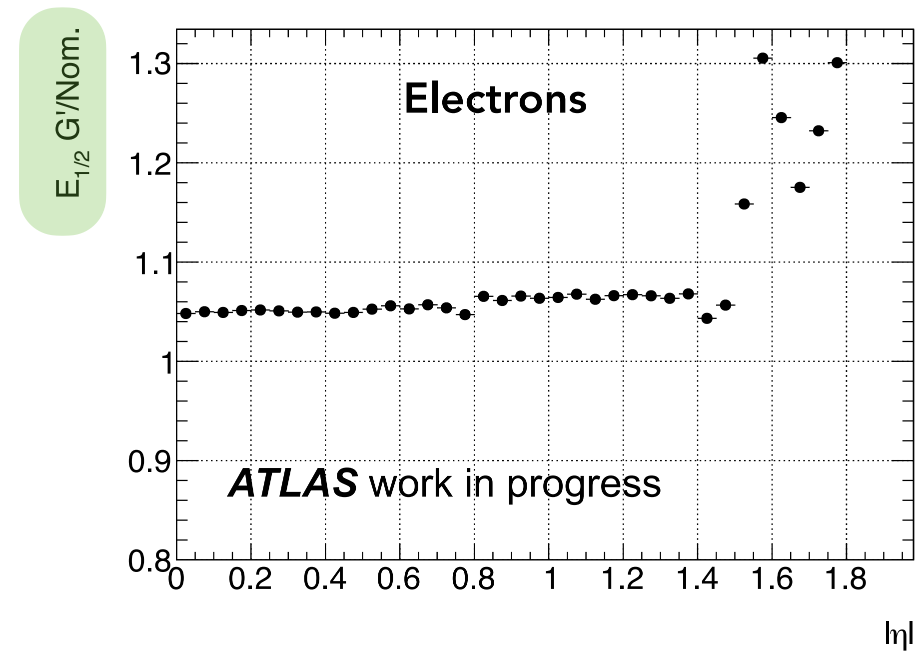
Closure test using G' sample

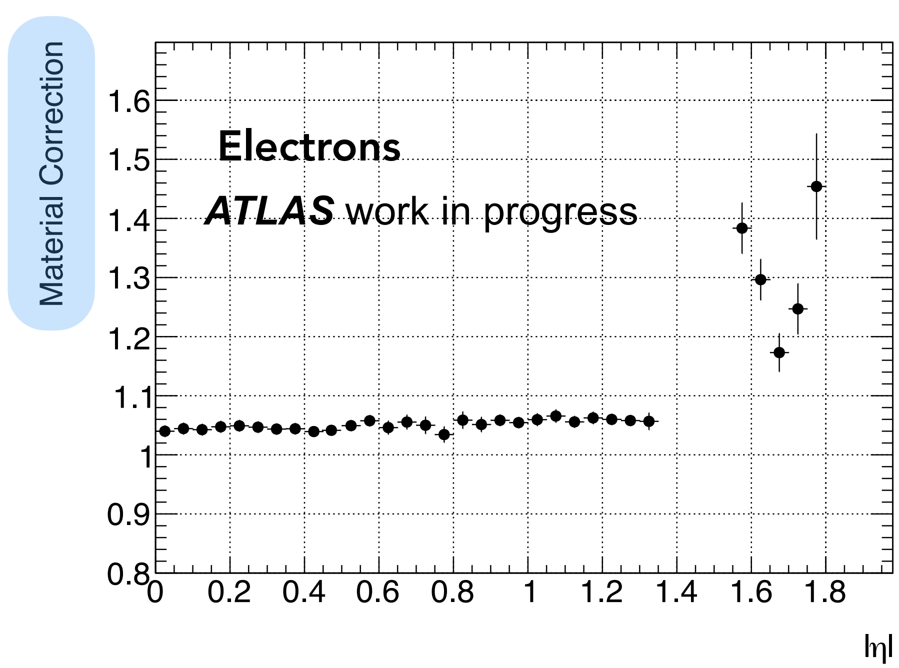
- Closure test on the recipe was performed using distorted geometry G' MC
- α_{PS} is calculated from the formula

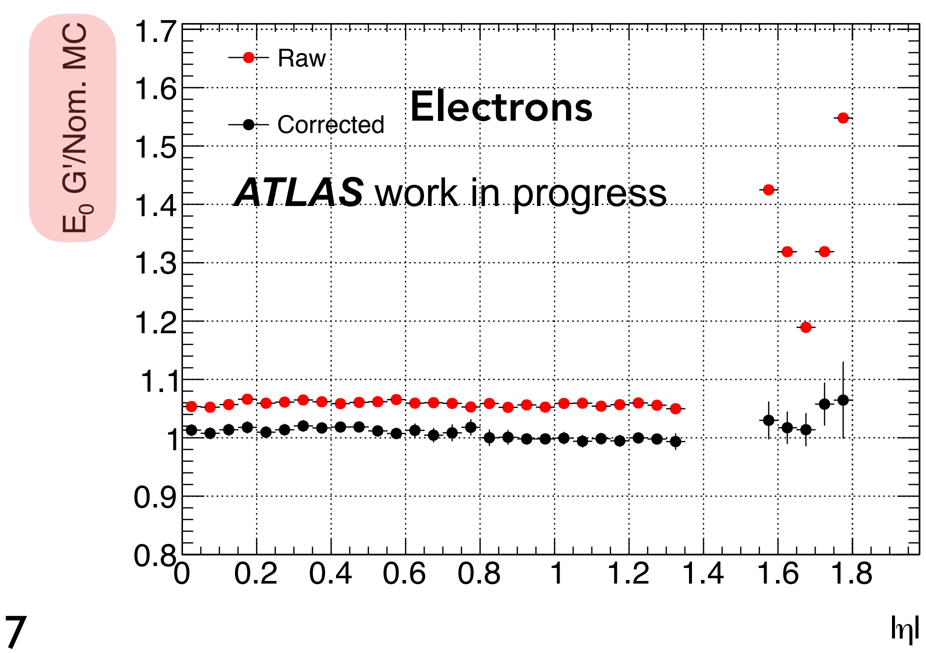
PS scale

$$\alpha_{PS}^{closure} = \frac{E_0^{G'}(\eta)}{E_0^{corr}(\eta)} \quad \text{where:} \quad \frac{E_0^{\mathrm{corr}}(\eta)}{E_0^{\mathrm{nom}}(\eta)} = 1 + A(\eta)\left(\frac{E_{1/2}^{\mathrm{G'}}(\eta)/E_{1/2}^{\mathrm{nom}}(\eta)}{b_{1/2}^{barrel,EC}} - 1\right)$$





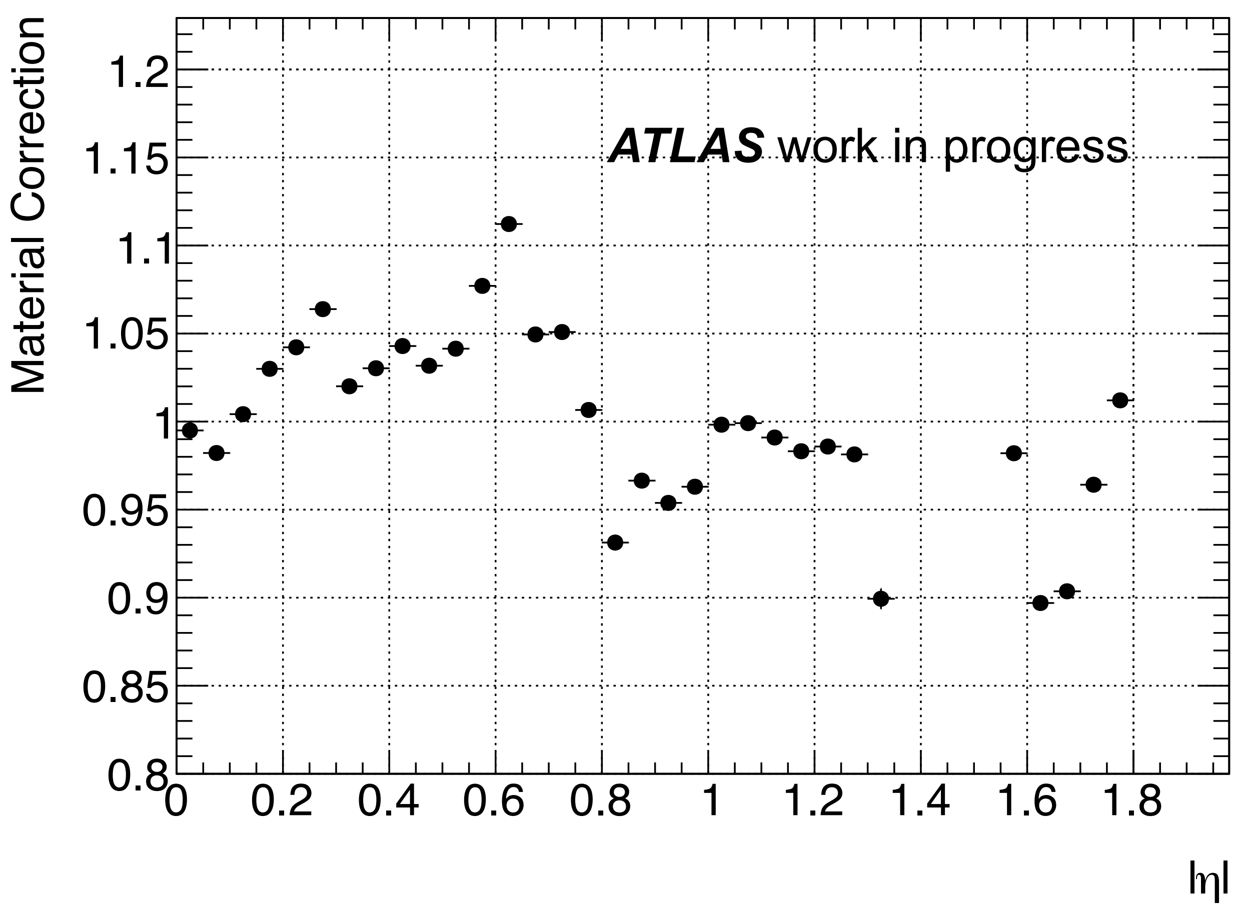


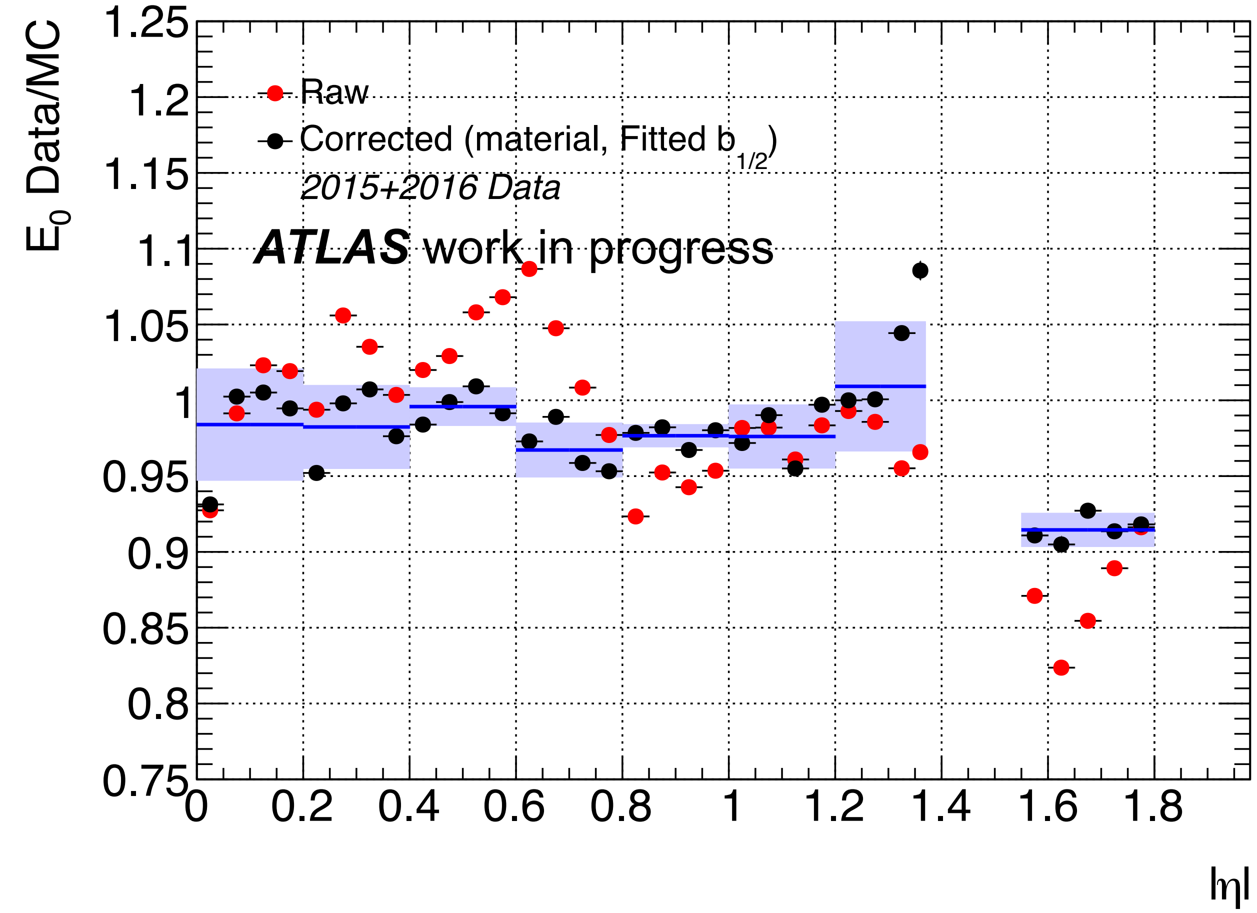


PS scale

Combining E_0, $E_{1/2}$ with fitted values of $b_{1/2}$ the total material correction is derived

Final α_{PS} values using 2015+2016 data

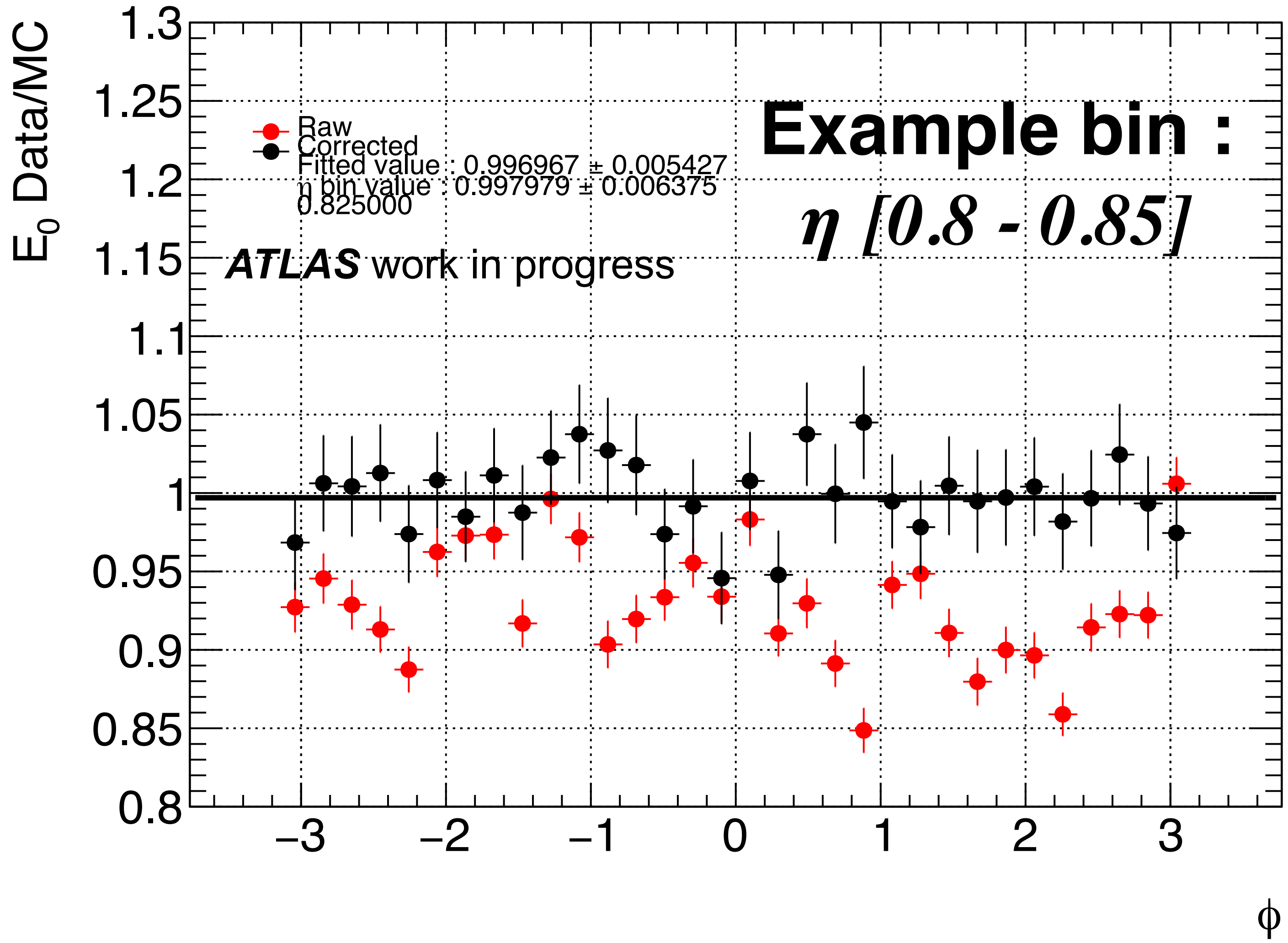




PS scale stability along ϕ

- **PS scale along ϕ**
  - performing ϕ dependent material correction for each η bin
    - using $A(\eta)$, $b_{1/2}(\eta)$

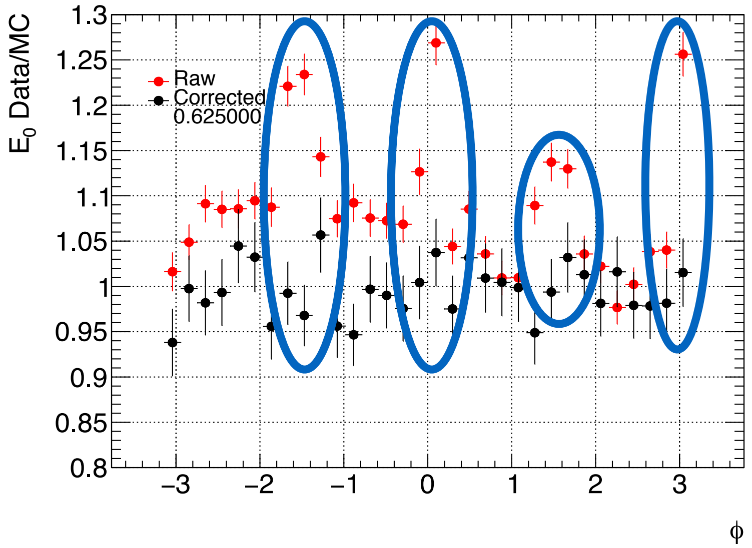
$$\frac{E_0^{\text{corr}}(\eta,\phi)}{E_0^{\text{nom}}(\eta,\phi)} = 1 + A(\eta)\left(\frac{E_{1/2}^{\text{data}}(\eta,\phi)}{E_{1/2}^{\text{nom}}(\eta,\phi)b_{1/2}(\eta)} - 1\right)$$

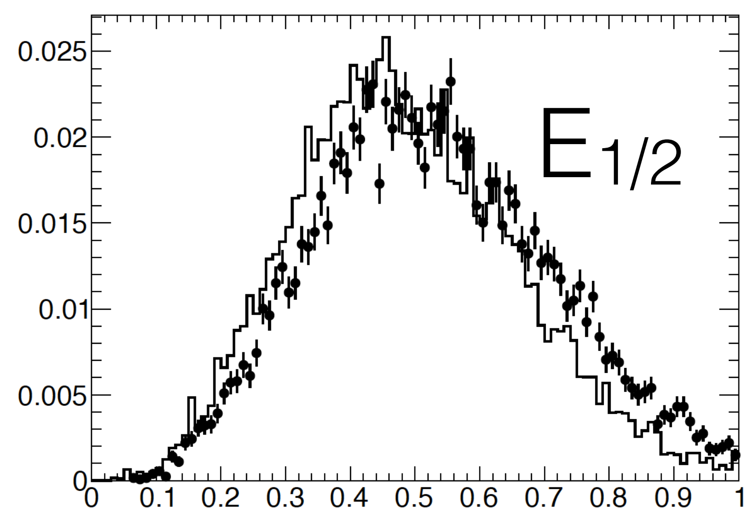


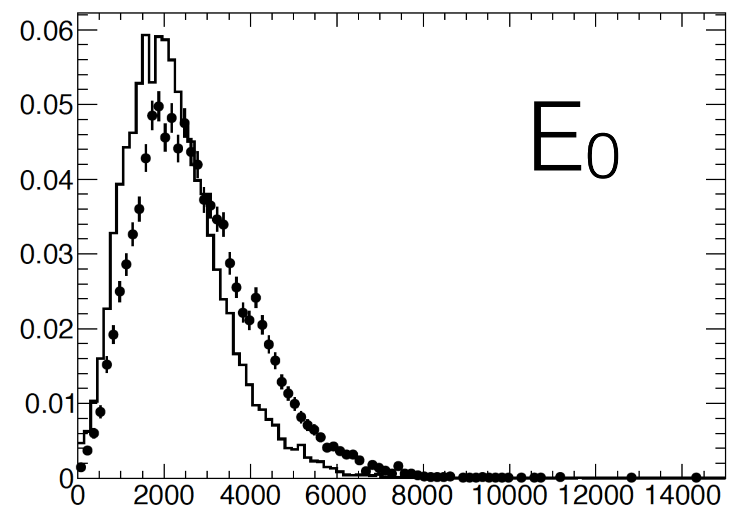
Material mis-modeling $\eta \simeq 0.6$

- Periodic structure was observed along phi for $\eta \simeq 0.6$
- Material effect is corrected using using PS scale material correction ⇒ doesn't affect PS scale
- Data-MC discrepancy in E0 and E12 indicate material issue

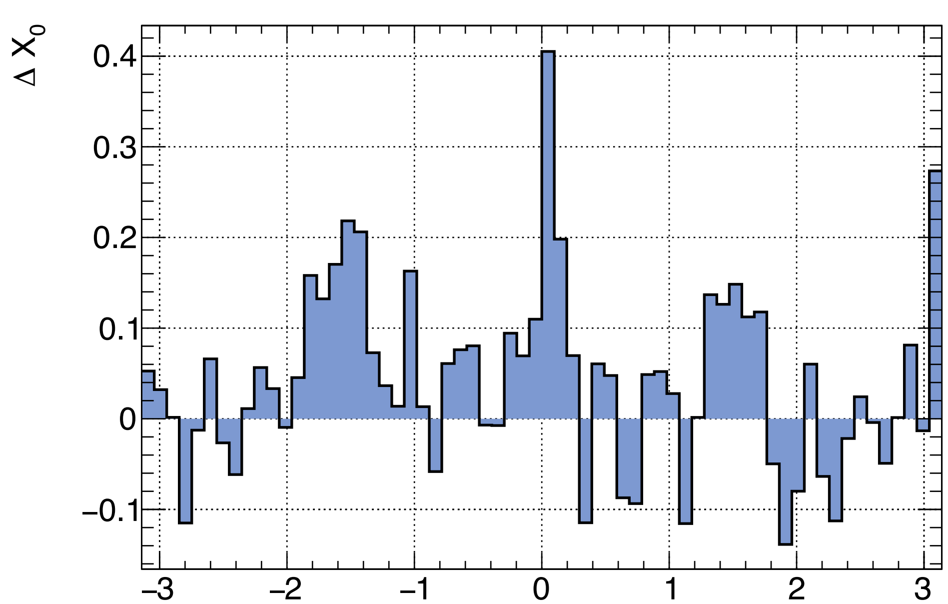
— MC • Data





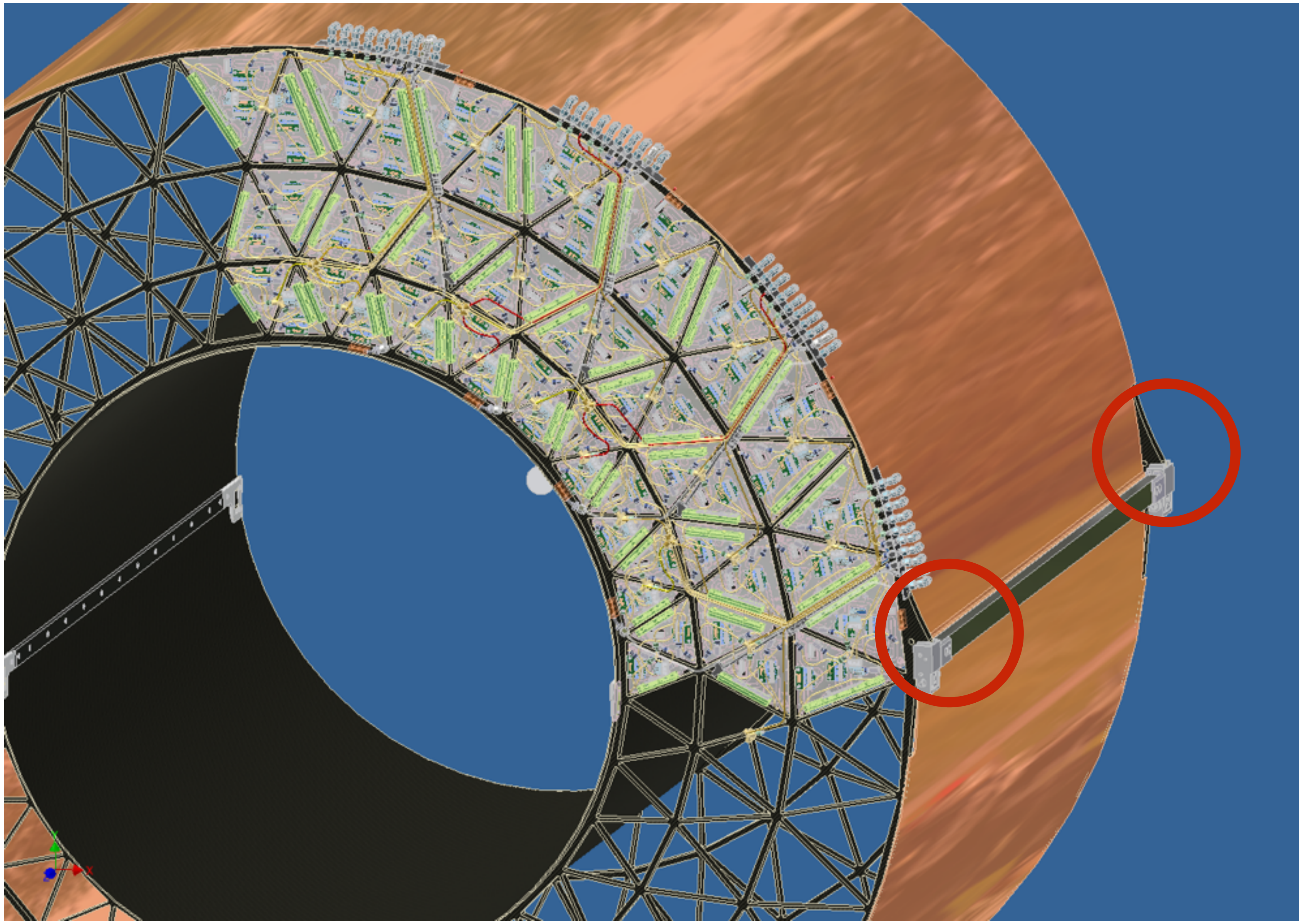


- Material estimates in terms of ΔX_0 :



Material mis-modeling $\eta=0.6$

- The mis-modelling is related to Transition Radiation Tracker services
  - Aluminium "pillars" used to slide the TRT barrel in case of LAr leakage
  - Exact TRT services budget is not included in the simulation



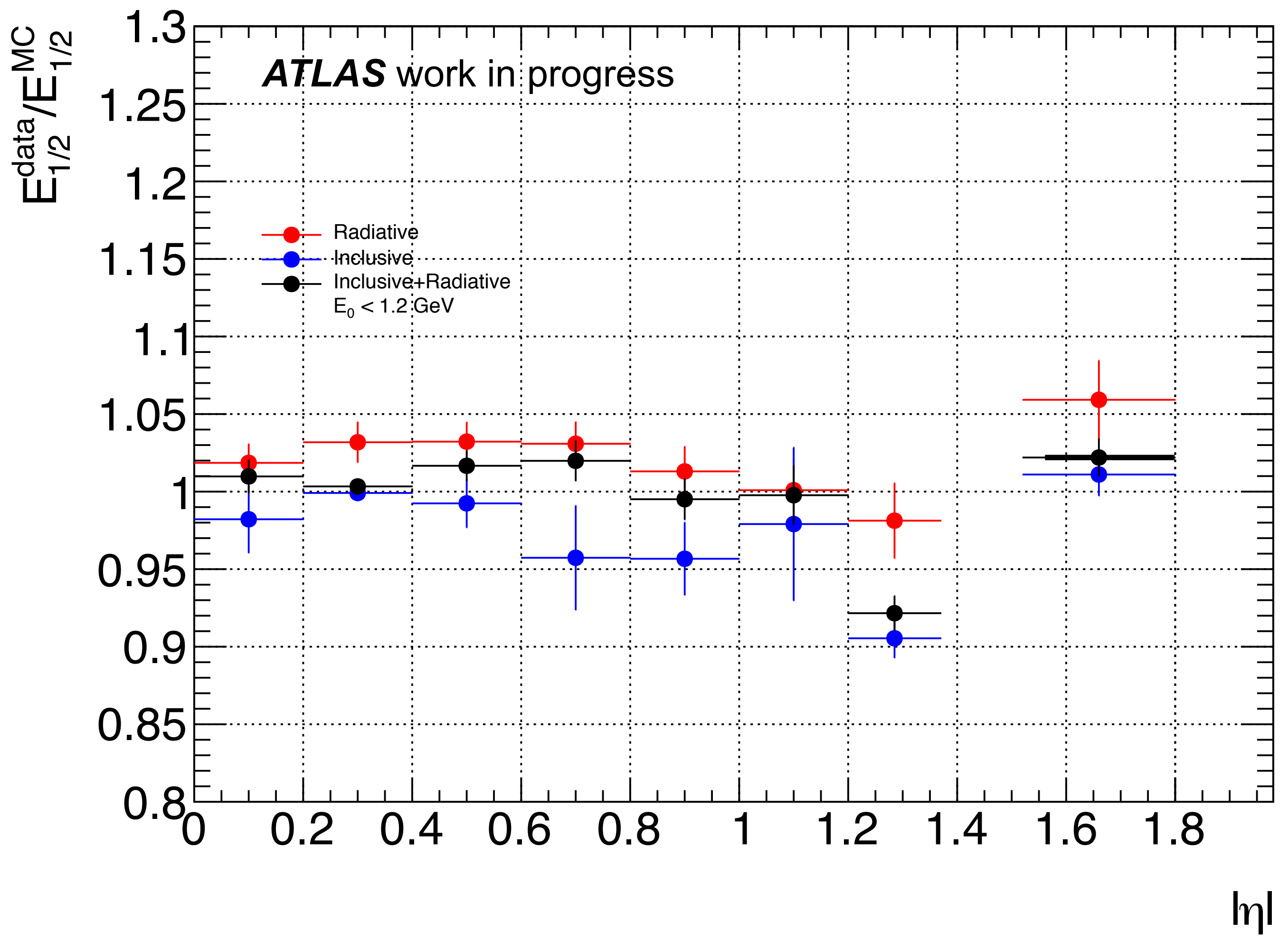
Conclusions

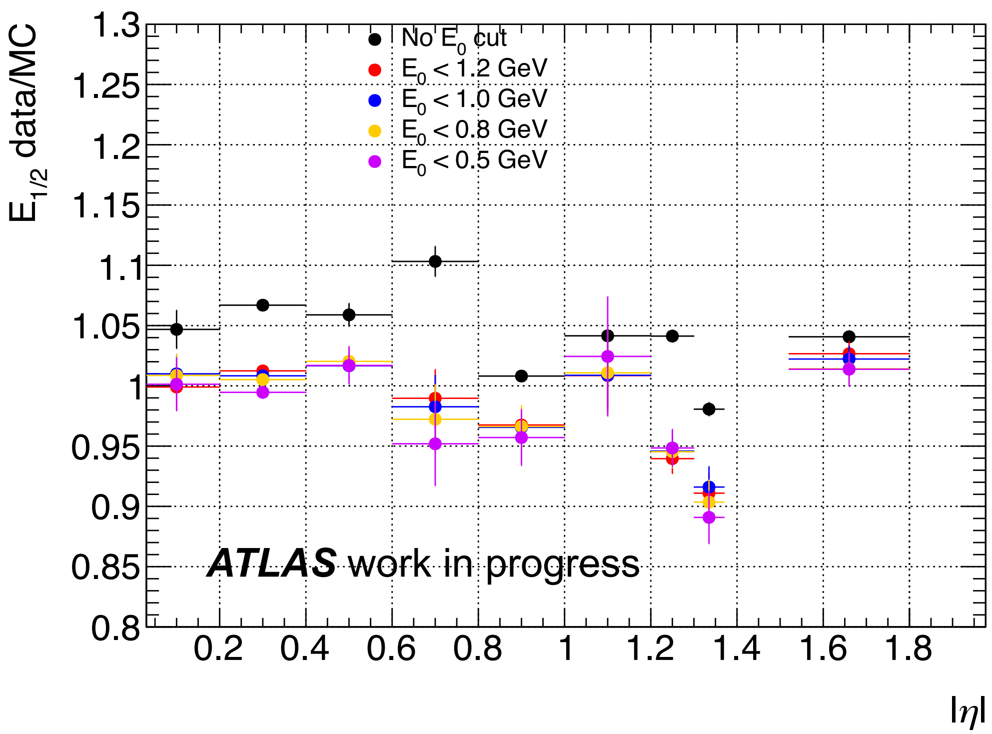
- PS scale can be measured by using the correlation with the strips and the second layer and estimate $A(\eta)$
- Unconverted photons with low PS activity can probe material after the presampler $b_{1/2}(\eta)$
- Combining $A(\eta)$, $b_{1/2}(\eta)$ and $E_{1/2}(\eta)$ removes material effect and the PS scale is measured
- PS scale is found symmetric along η, ϕ

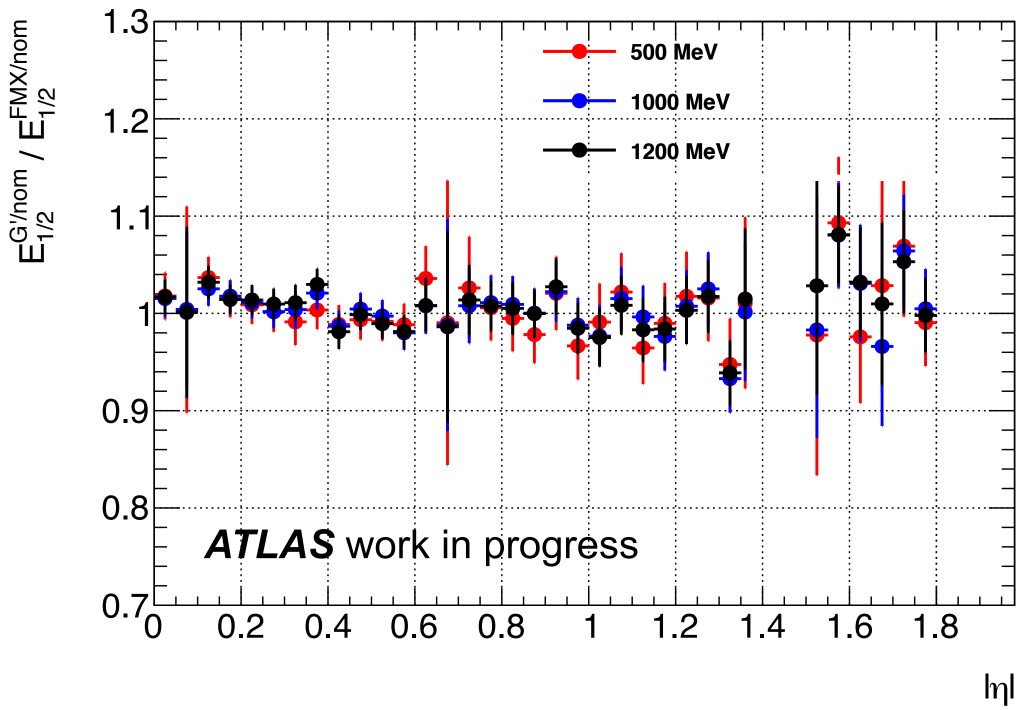
Back up

PS/Accordion material effects $b_{1/2}(\eta)$

- Radiative Z samples ($Z \to \mu\mu\gamma$)
  - μ p_T > 12 GeV, γ p_T > 10 GeV
  - FSR : $m_{\mu\mu} \in$ [50-83] GeV, $m_{\mu\mu\gamma} \in$ [80-100] GeV
  - f_1 **> 0.1**
- Inclusive photon ntuples (v12)
  - **p_T > 147 GeV**
- Tight, *FixedcutTight Isolation* and unconverted
- ***Remove PS HV faulty cells***
- **E_0 veto**



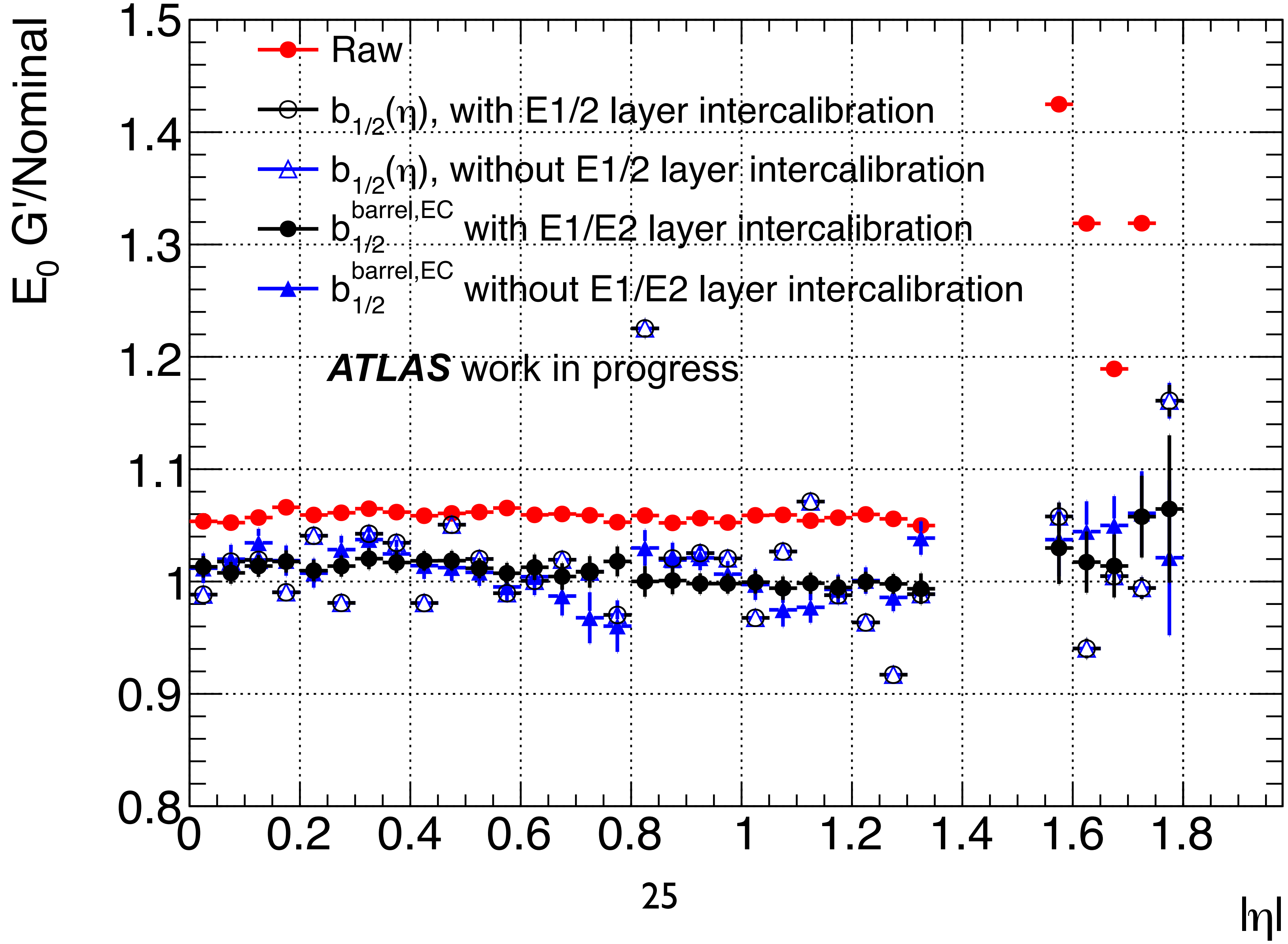




Impact of E1/E2 layer intercalibration

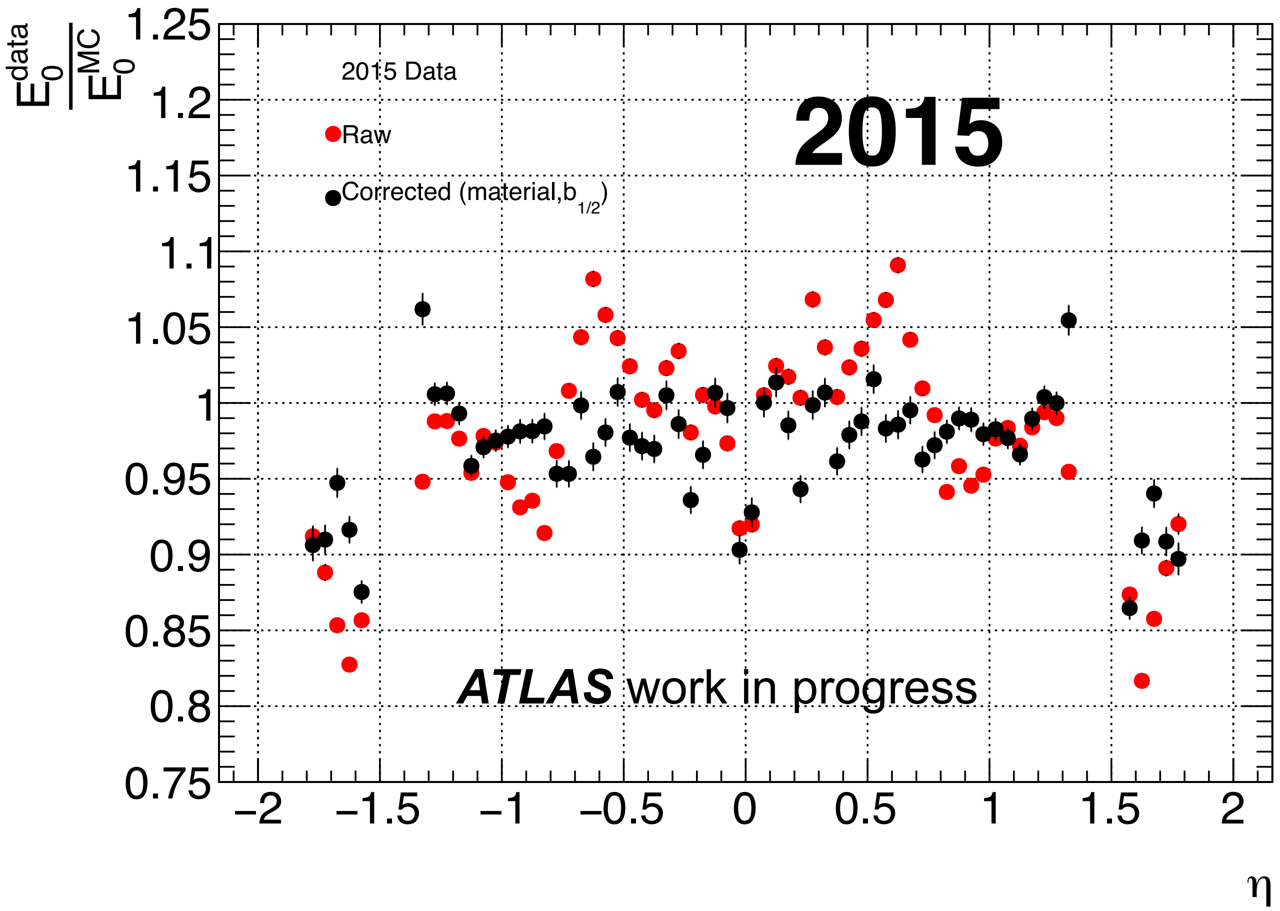
- **Introducing η dependent $E_{1/2}$ mis-calibration** $\alpha_{1/2}(\eta) = E_{1/2}^{muons}(\eta)$ **to** $E_{1/2}^{G',miscal} = E_1^{G'}/(\alpha_{1/2}E_2^{G'})$ **to both electrons and photons ($b_{1/2}$) of MC G'** *[mis-calibration taken from data]*
- Material correction formula implemented in order to cancel out $E_{1/2}$ inter-calibration corrections between electrons and photons $$\frac{E_0^{\rm corr}(\eta)}{E_0^{\rm nom}(\eta)} = 1 + A(\eta)\left(\frac{E_{1/2}^{G'}(\eta)/E_{1/2}^{\rm nom}(\eta)}{b_{1/2}^{barrel,EC}} - 1\right)$$

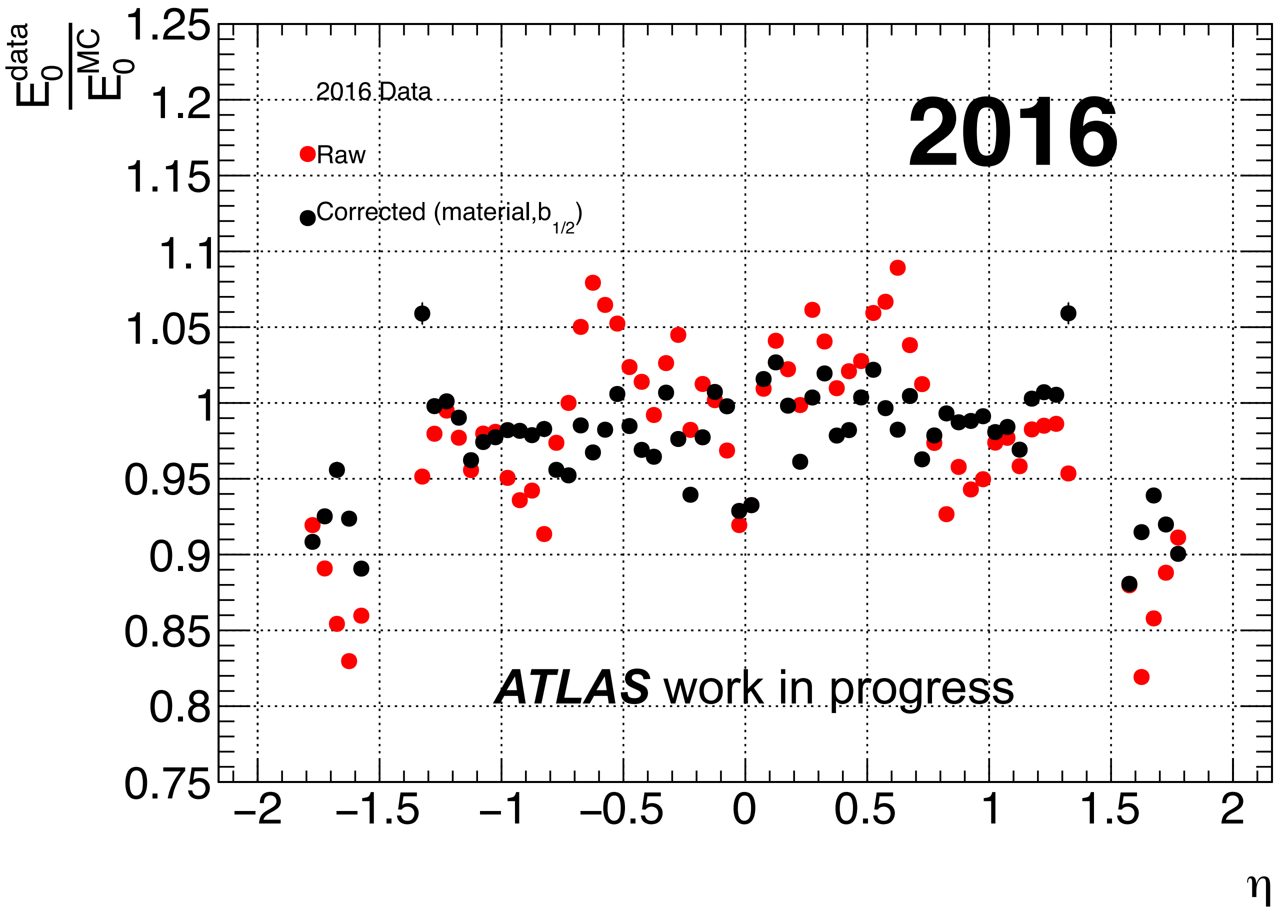
⚠ ***$b_{1/2}$* is fitted, hence *$E_{1/2}$* inter-calibration corrections don't fully cancel**



PS scale stability along η

- PS scale found symmetric along η





Dataset selection and configuration

DS	**Electrons** **2016 Data (All year (A-L) Lumi: 33.9 fb^{-1})** data16_13TeV.*.physics_Main.merge.DAOD_EGAM1.f694_m1583_p2667 **2015 Data** data15_13TeV.*.physics_Main.merge.DAOD_EGAM1.r7562_p2521_p2667* **MC** nominal geo. : mc15_13TeV.361106.PowhegPythia8EvtGen_AZNLOCTEQ6L1_Zee.merge.DAOD_EGAM1.e3601_s2576_s2132_r7725_r7676_p2666 modified geo. : *list in backup*
GRL	data16_13TeV.periodAllYear_DetStatus-v83-pro20-15_DQDefects-00-02-04_PHYS_StandardGRL_All_Good_25ns.xml data15_13TeV.periodAllYear_DetStatus-v79-repro20-02_DQDefects-00-02-02_PHYS_StandardGRL_All_Good_25ns.xml
Trigger	HLT_2e17_lhvloose_nod0
Likelihood	Medium
Isolation	Loose
PRW	**Conf file:** CalibrationSelection/user.turra.mc15_13TeV.361106.PowhegPythia8EvtGen_AZNLOCTEQ6L1_Zee.merge.AOD.e3601_s2576_s2132_r7725_r7676_prw.root **LumiCalc:** CalibrationSelection/ilumicalc_histograms_None_297730-308084_OflLumi-13TeV-005.root
ESM model	es2016PRE
η	$\|\eta\| < 2.47$
p_T	$p_T > 27$ GeV
PV Zmax	150
Z^0	2 opposite charge electrons, $80 < m_{ee} < 100$ GeV