# Intercalibration of the first and second layers of the electromagnetic calorimeter in the ATLAS detector

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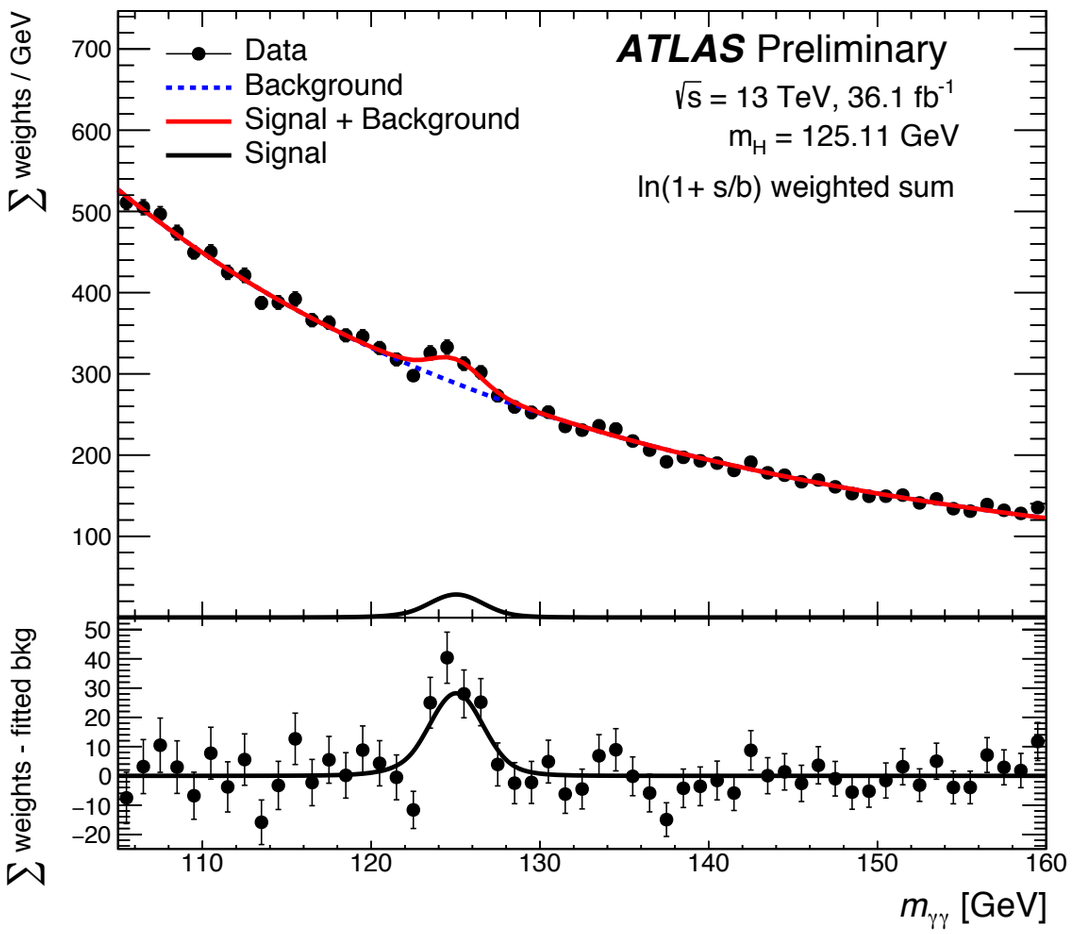
(LAL - Orsay)

PHENIICS Fest — May 28th, 2018

# Once upon a time…

- Precision measurement in the Standard Model: **Higgs mass** and couplings, W boson mass, …

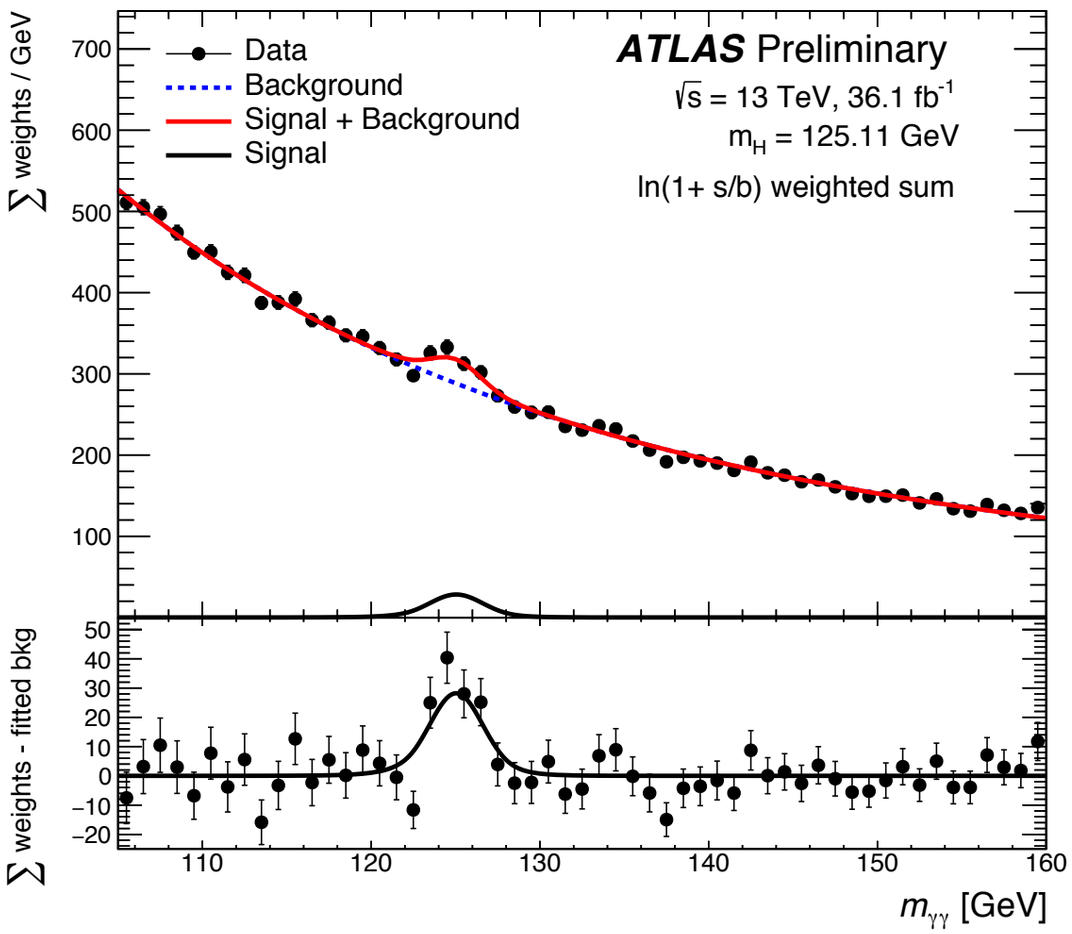



$m_H = 125.11 \pm 0.21(\text{stat}) \pm 0.36(\text{syst})$ GeV

| Source | $\delta m_H^{\gamma\gamma}$ [MeV] |
|---|---|
| LAr cell non-linearity | $\pm 200$ |
| LAr layer calibration | $\pm 190$ |
| Non-ID material | $\pm 120$ |
| Lateral shower shape | $\pm 110$ |
| ID material | $\pm 110$ |
| Conversion reconstruction | $\pm 50$ |
| $Z \to ee$ calibration | $\pm 50$ |
| Background model | $\pm 50$ |
| Primary vertex effect on mass scale | $\pm 40$ |
| Resolution | $^{+20}_{-30}$ |
| Signal model | $\pm 20$ |

# Once upon a time…

- Precision measurement in the Standard Model: **Higgs mass** and couplings, W boson mass, …
- **Starting to be limited by systematics**. **Work needed!**

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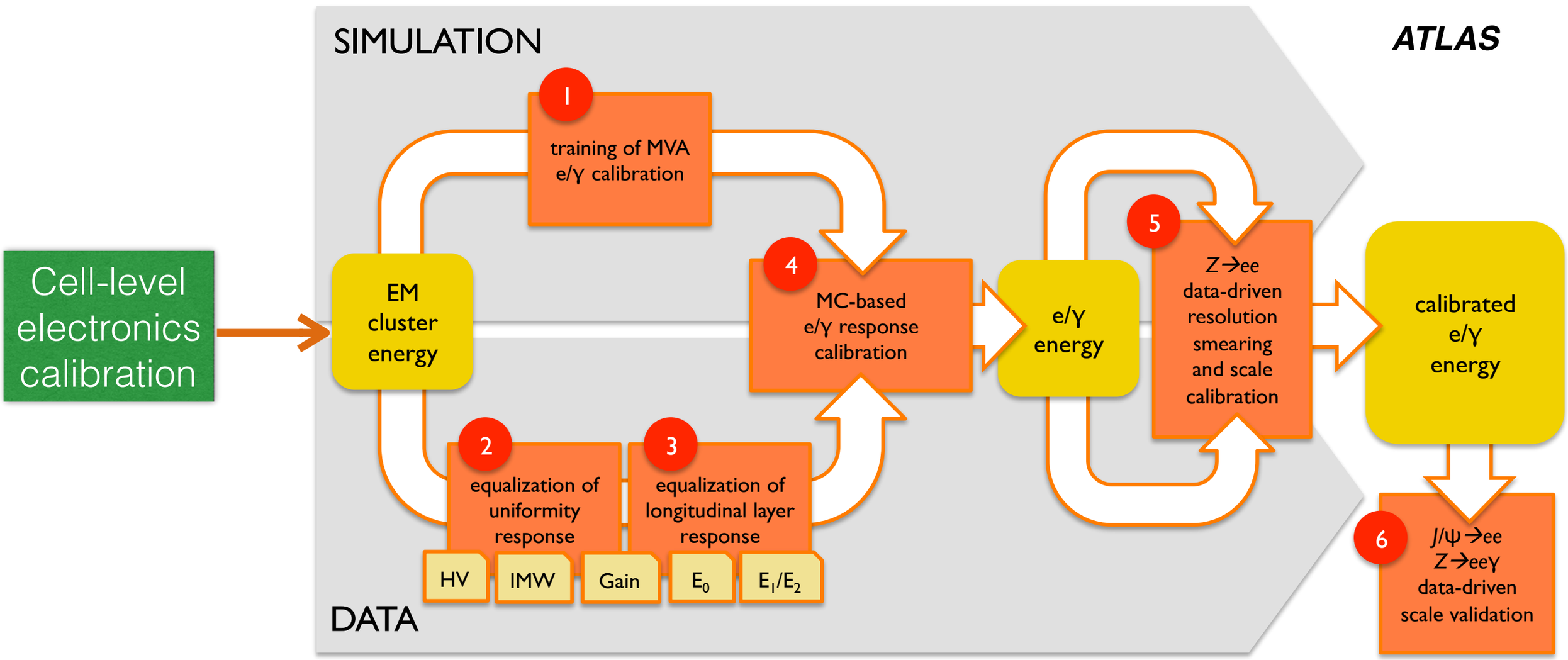

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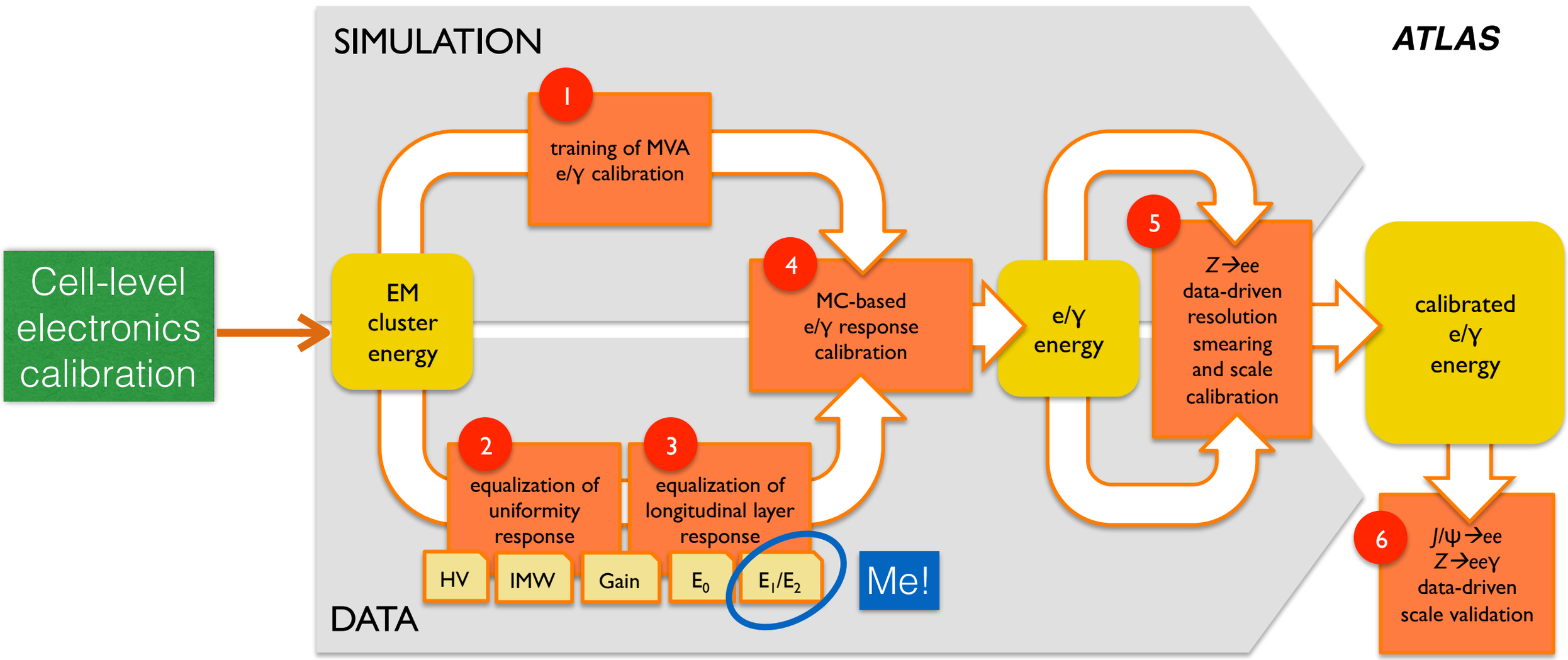
- Here: “E1/E2”



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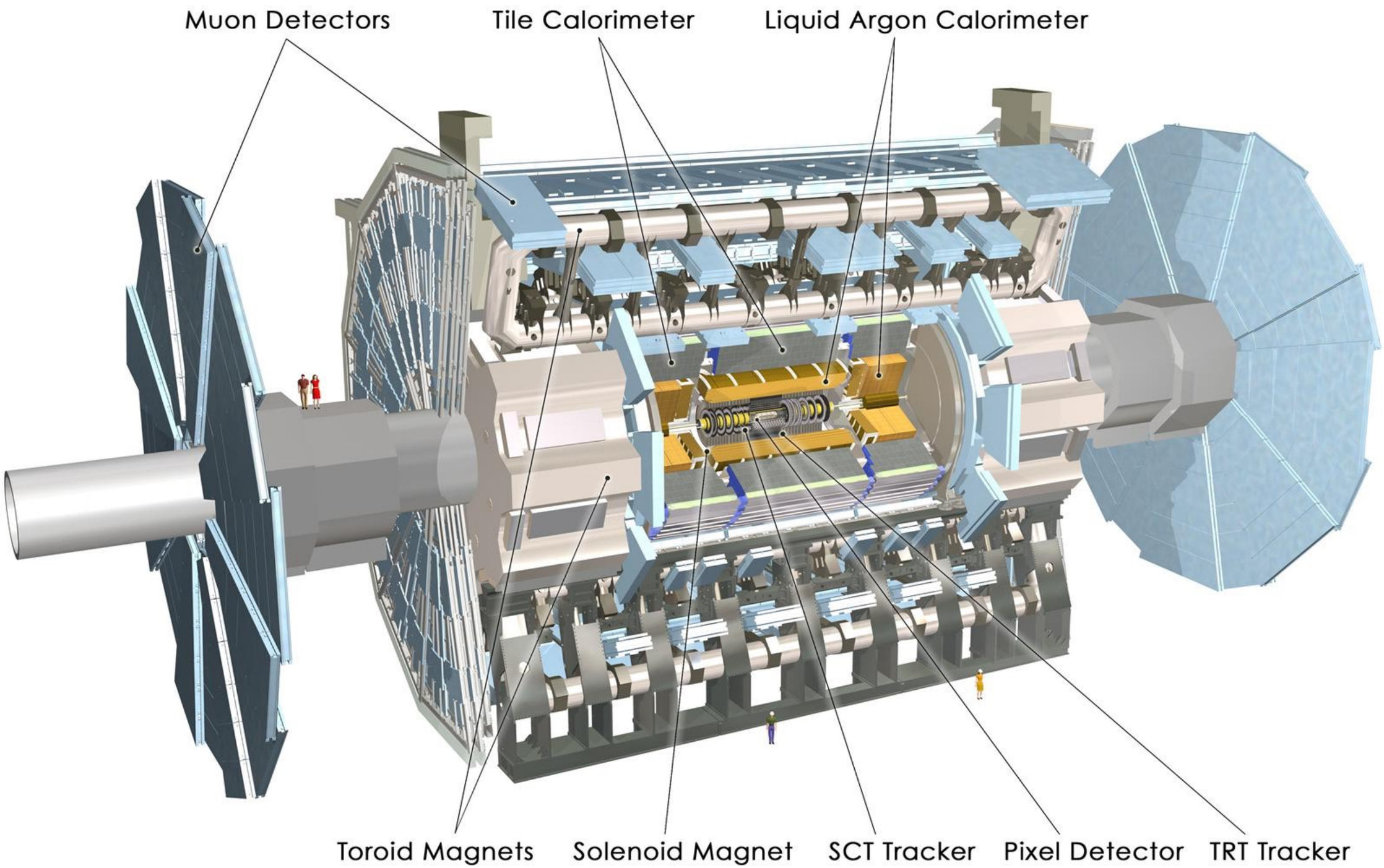
Muon Detectors
Tile Calorimeter
Liquid Argon Calorimeter
Toroid Magnets
Solenoid Magnet
SCT Tracker
Pixel Detector
TRT Tracker

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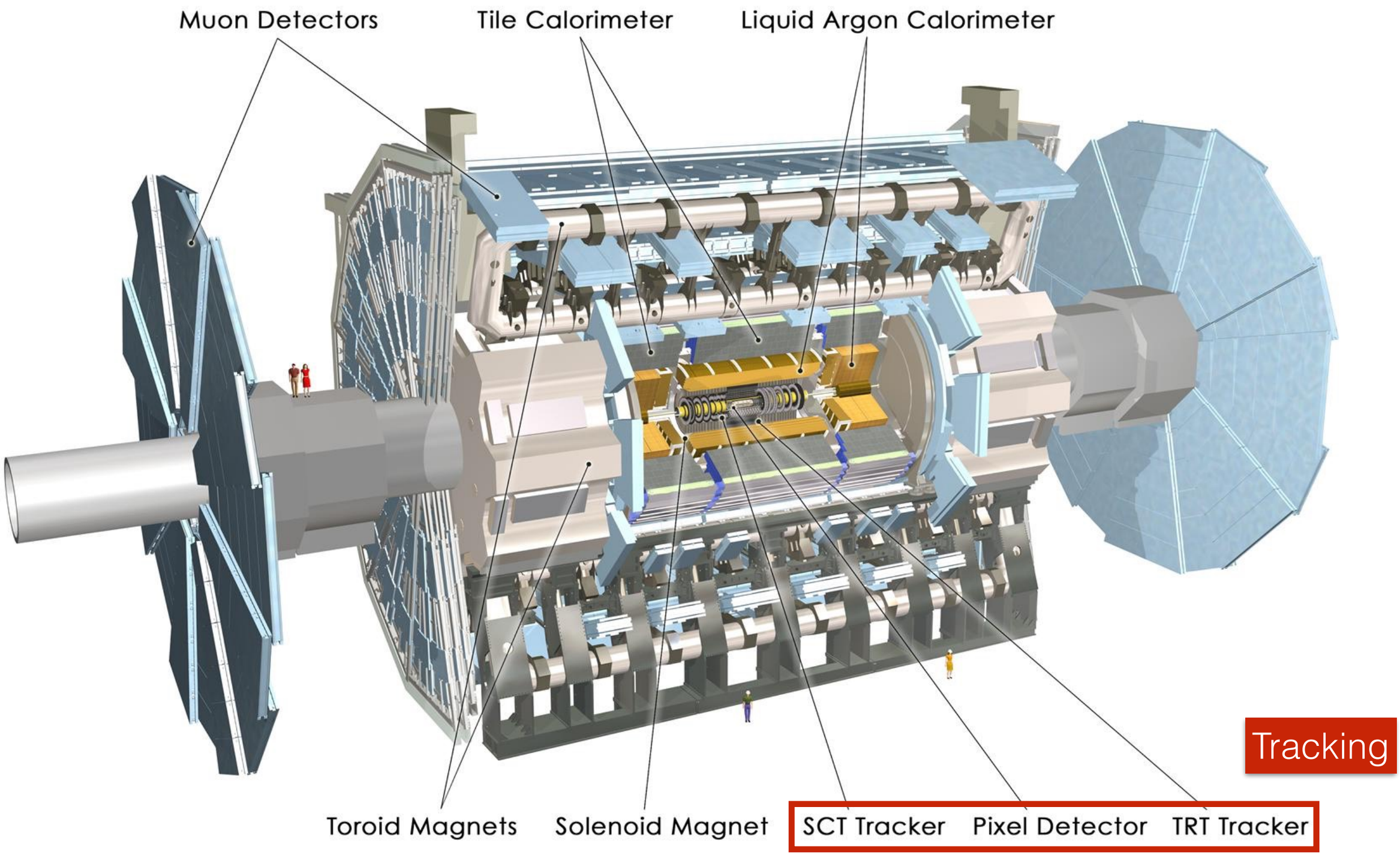
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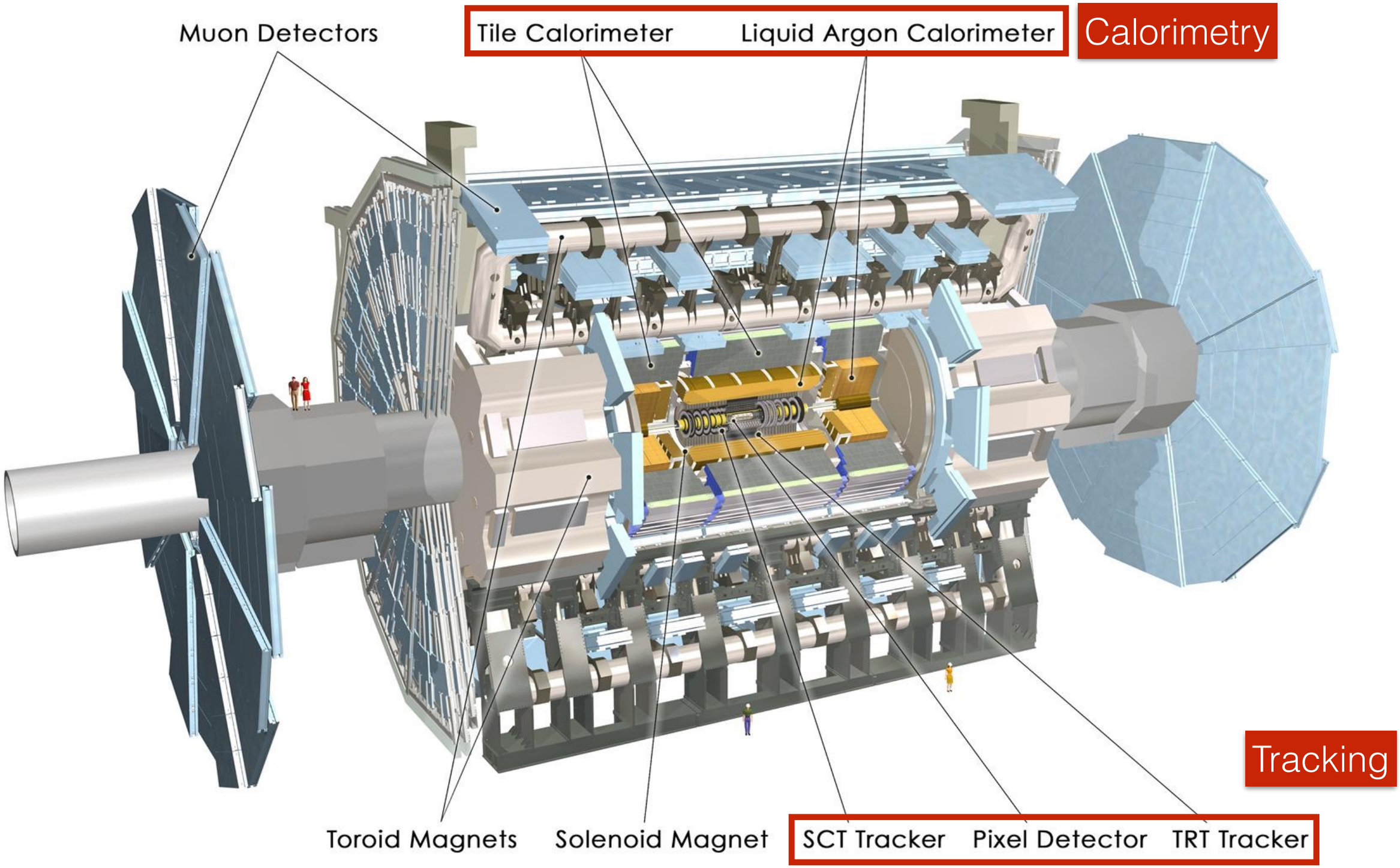
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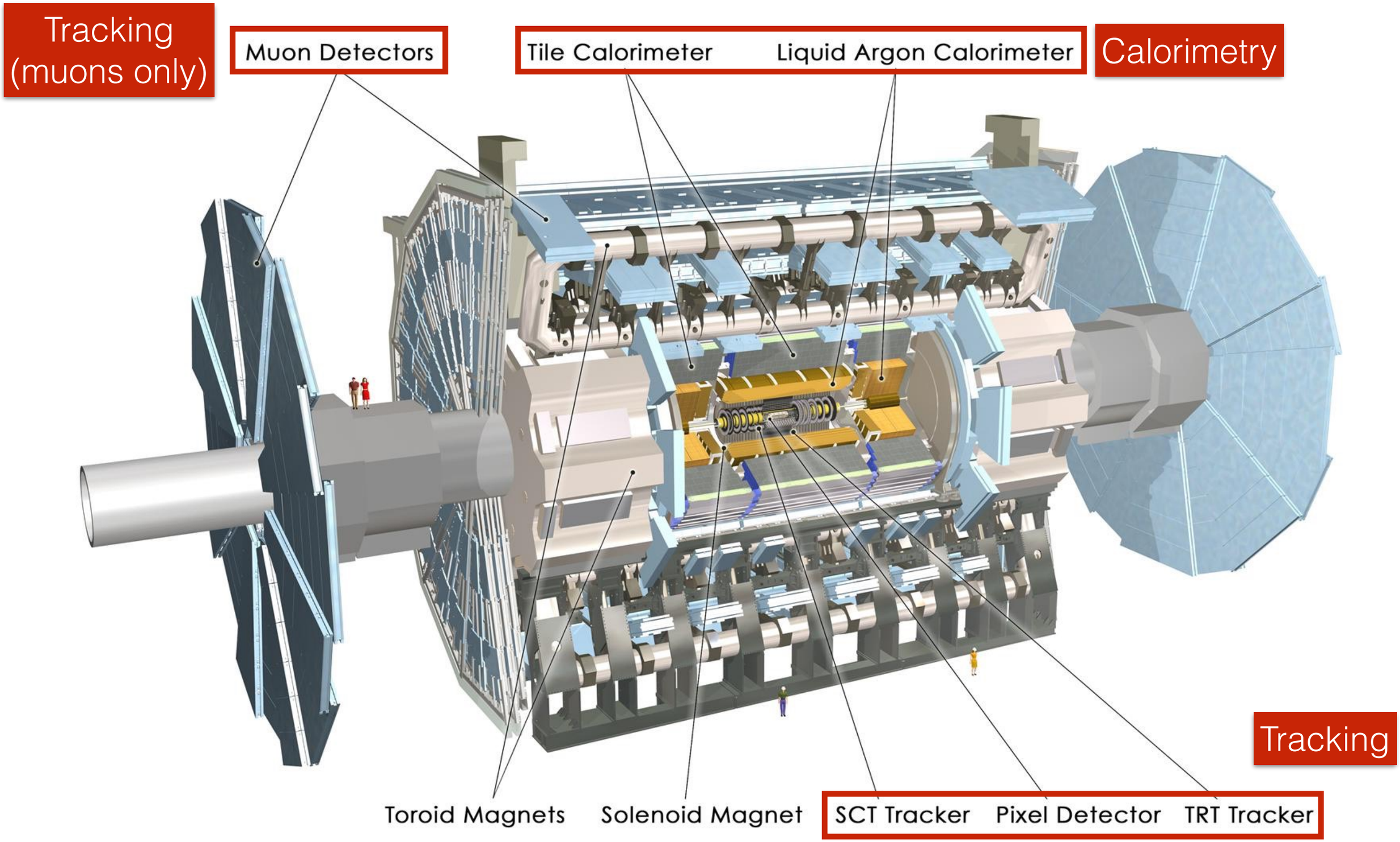
Tracking (muons only)
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Pixel Detector
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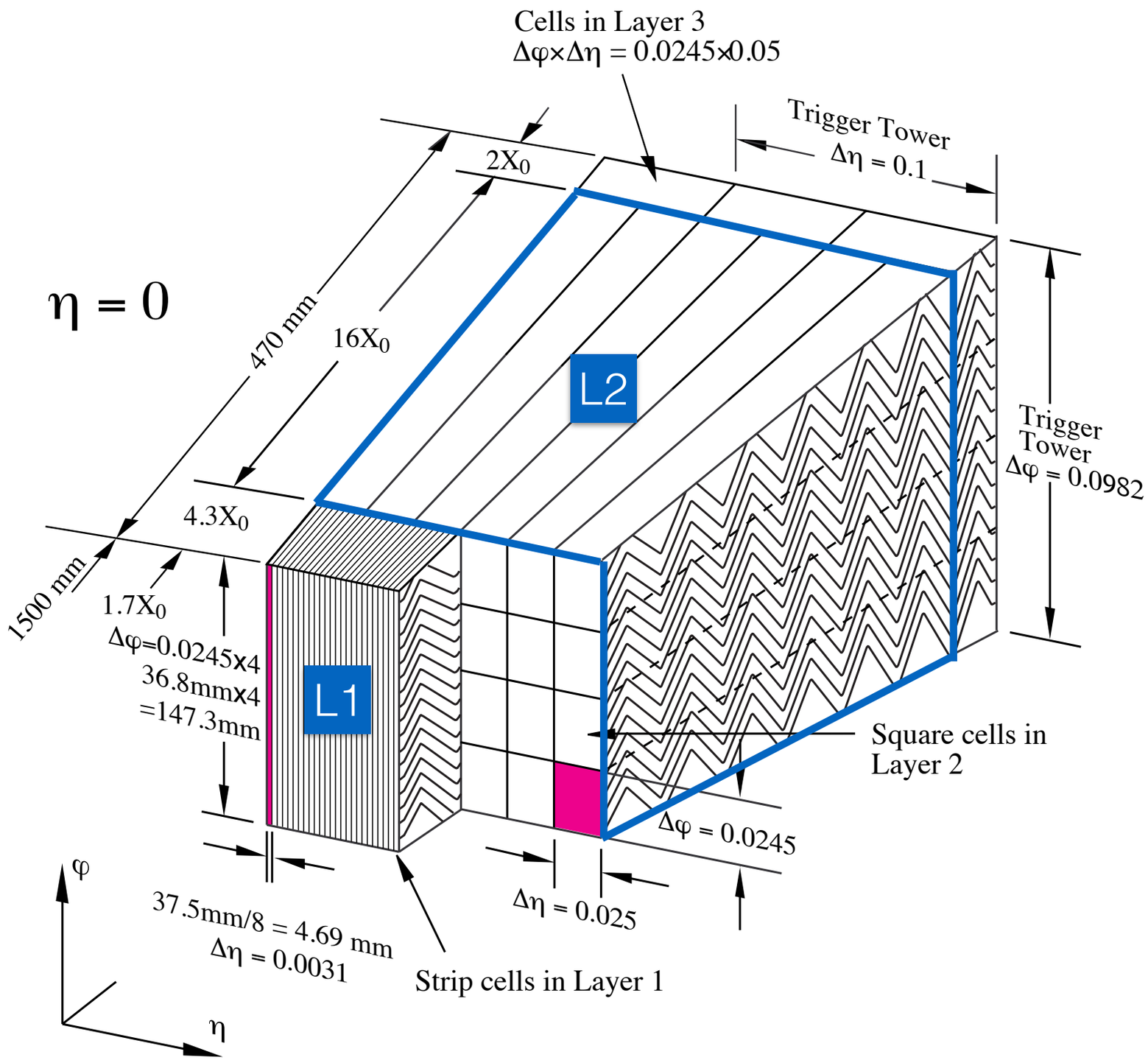
Cells in Layer 3
Δφ×Δη = 0.0245×0.05
Trigger Tower
Δη = 0.1
2X0
η = 0
470 mm
16X0
L2
Trigger
Tower
Δφ = 0.0982
4.3X0
1500 mm
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Δφ=0.0245x4
36.8mmx4
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L1
Square cells in
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Δφ = 0.0245
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37.5mm/8 = 4.69 mm
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Strip cells in Layer 1
η

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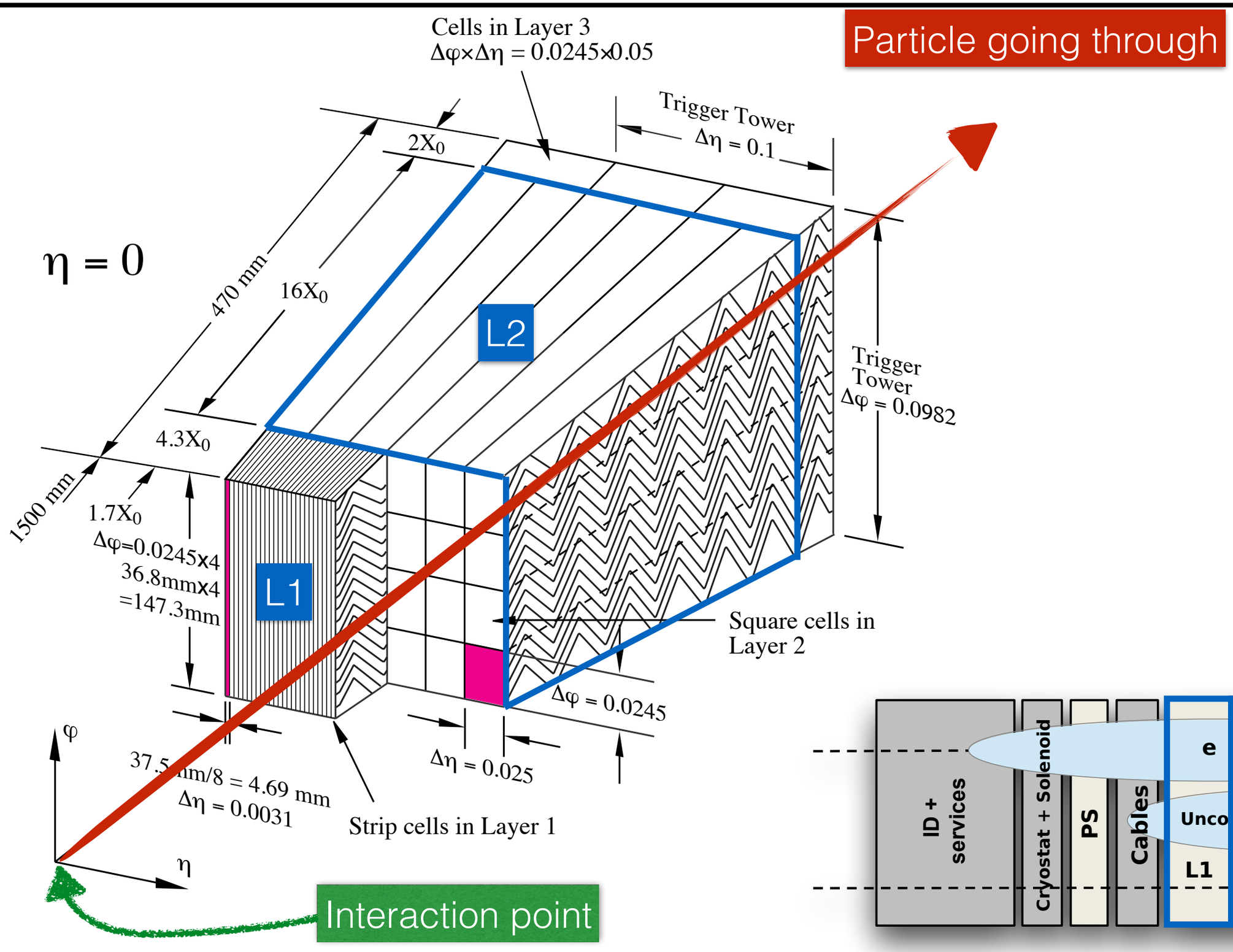
Particle going through
Cells in Layer 3
Δφ×Δη = 0.0245×0.05
Trigger Tower
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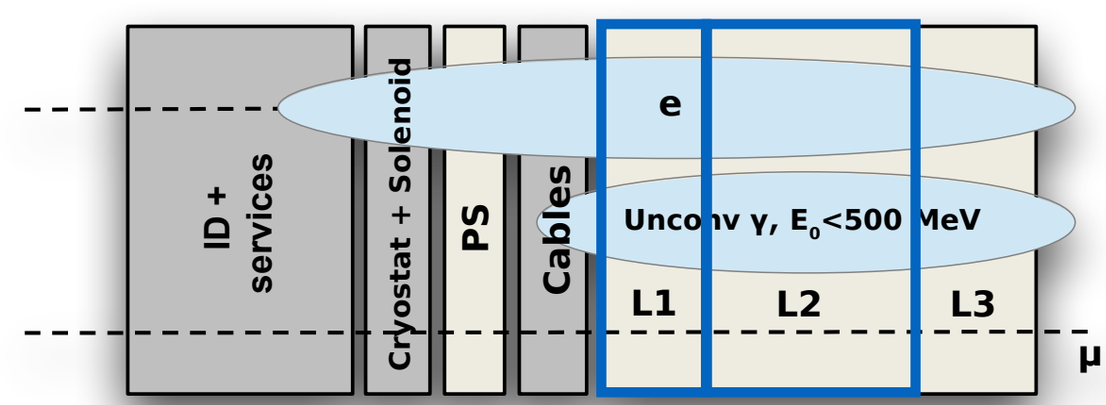
Interaction point


ID +
services
Cryostat + Solenoid
PS
Cables
e
Unconv γ, E0<500 MeV
L1
L2
L3
μ

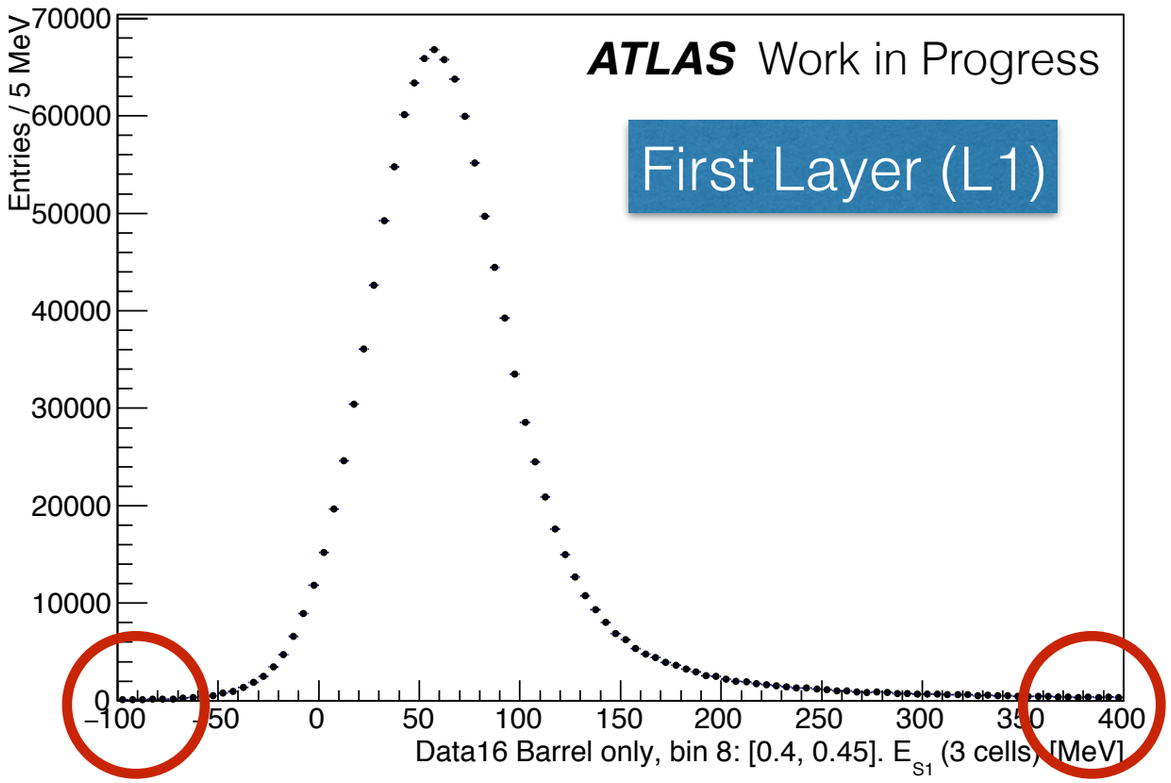
# E1/E2 intercalibration method

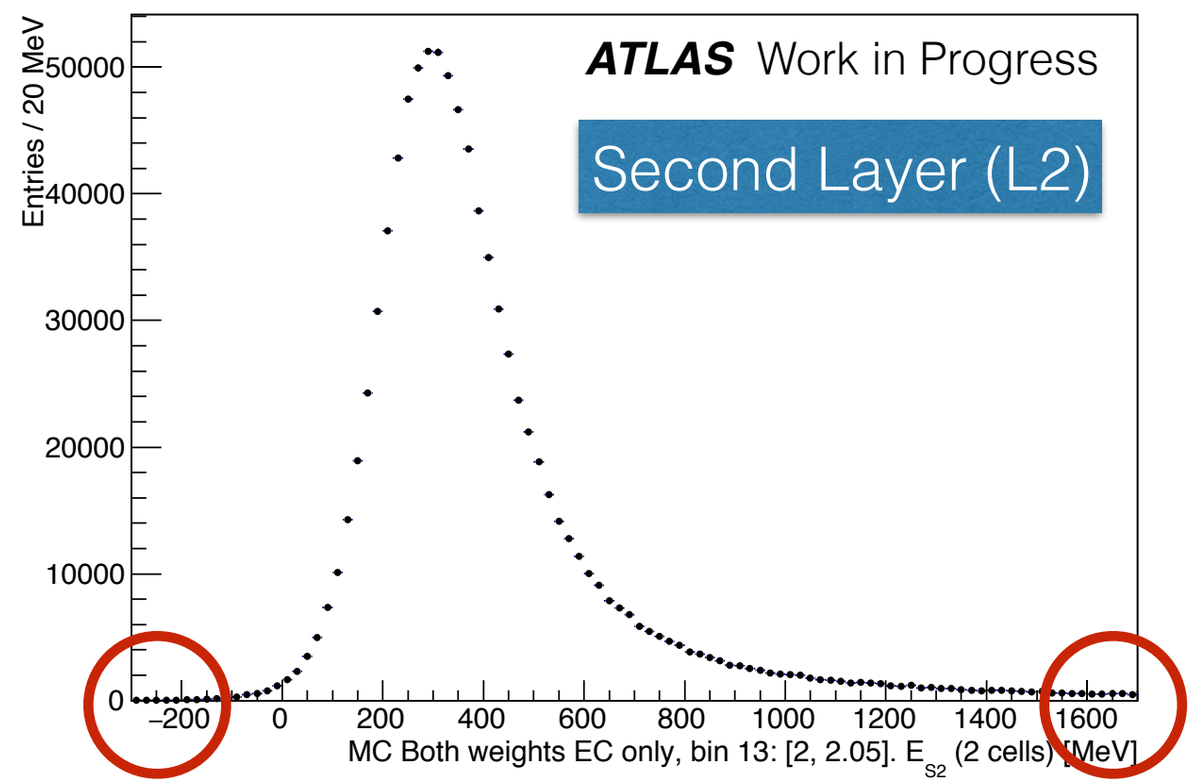
- **Goal**: **correct** for
  - the **residual electronics miscalibration**
  - **cross-talk** effects

# E1/E2 intercalibration method

- **Goal**: **correct** for
  - the **residual electronics miscalibration**
  - **cross-talk** effects
- How? **Use muons**!
  - **Energy deposited** in the calorimeter
    - **only depends on length** of active material (Liquid Argon) passed through,
    - is **insensitive to upstream material** (tracker, structures…) effects.
  - **Simple deposit**:
    - **No shower** (on the contrary of electrons) able to probe very finely the detector (infra cell-level)
    - Easily **modelled with a Landau distribution**.

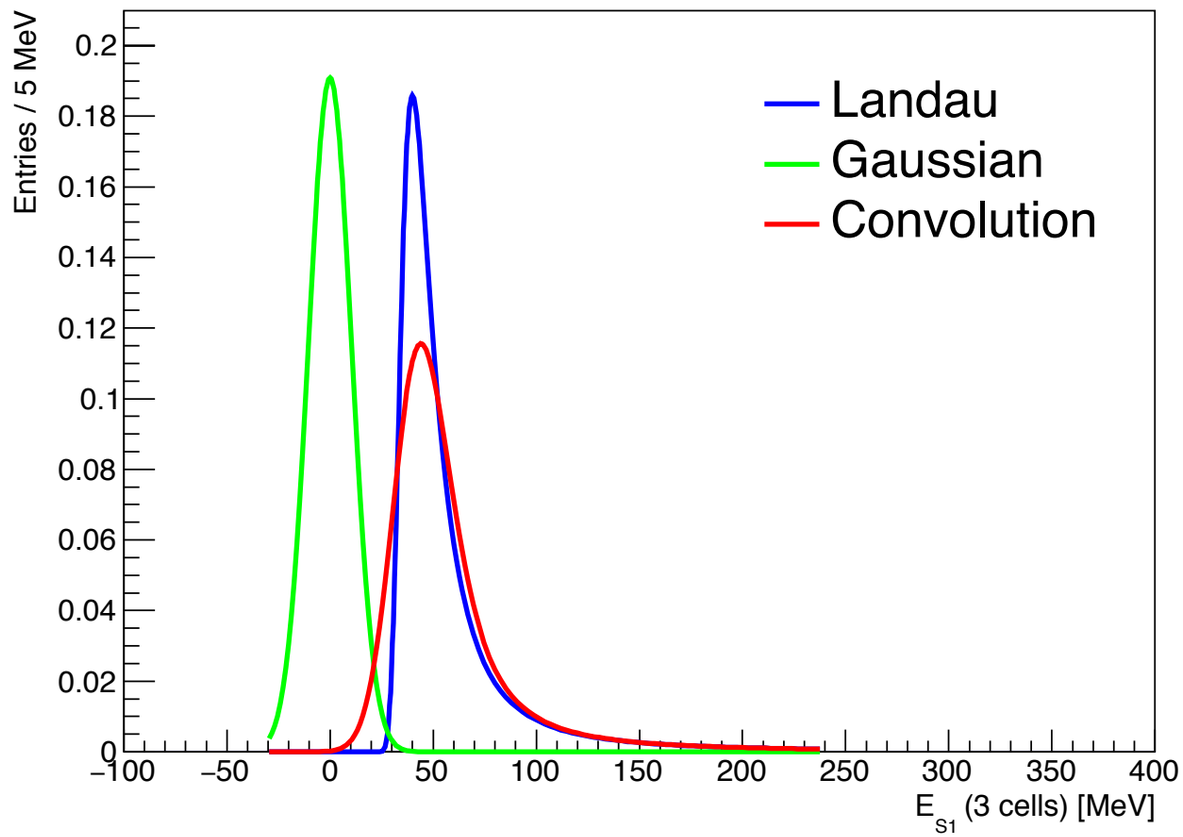
# Step 1: muon energy deposit




- Deeper cell in L2 → larger energy deposit.
- **Small energy deposit**: typically
  - 50 MeV in L1 (close to the noise level),
  - 270 MeV in L2 (3-4 times noise level).

# Step 2: fit the distribution



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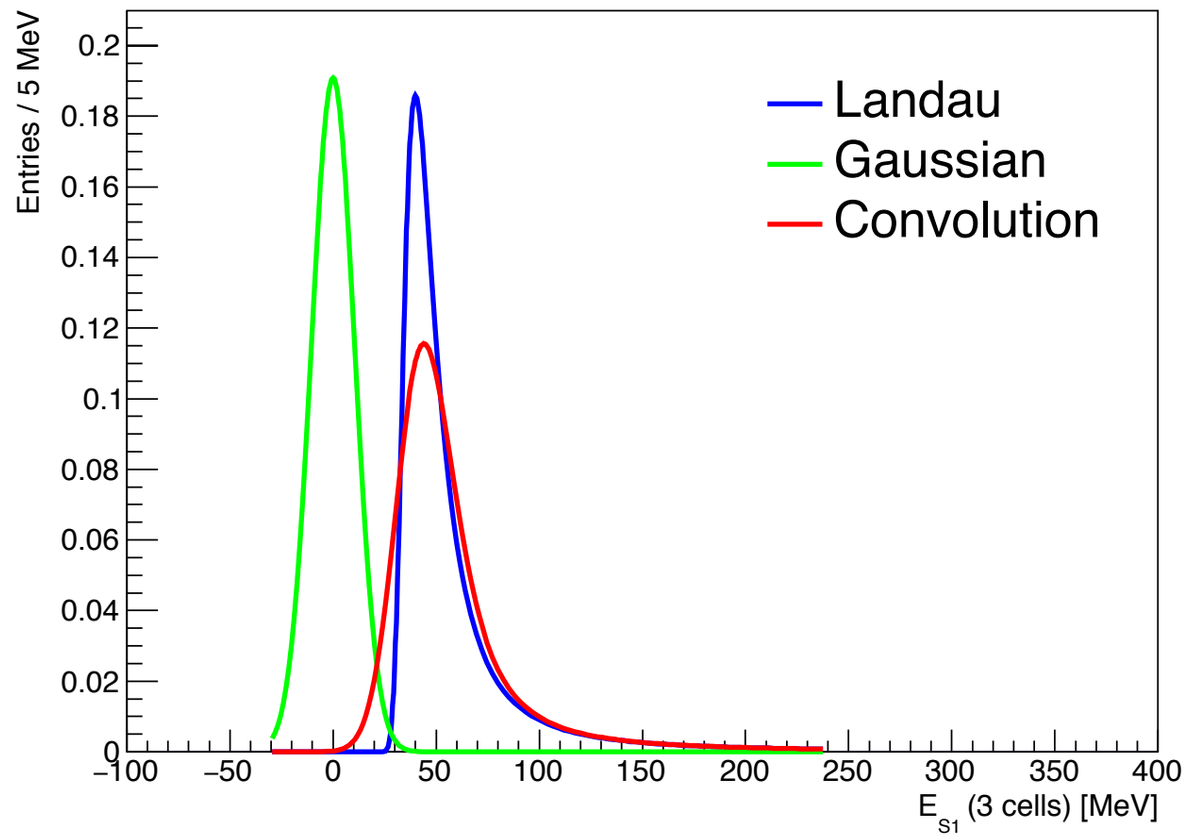


**Muon energy deposit (MIP): Landau distribution**

**Noise (electronic + other): Gaussian distribution, centred at 0**

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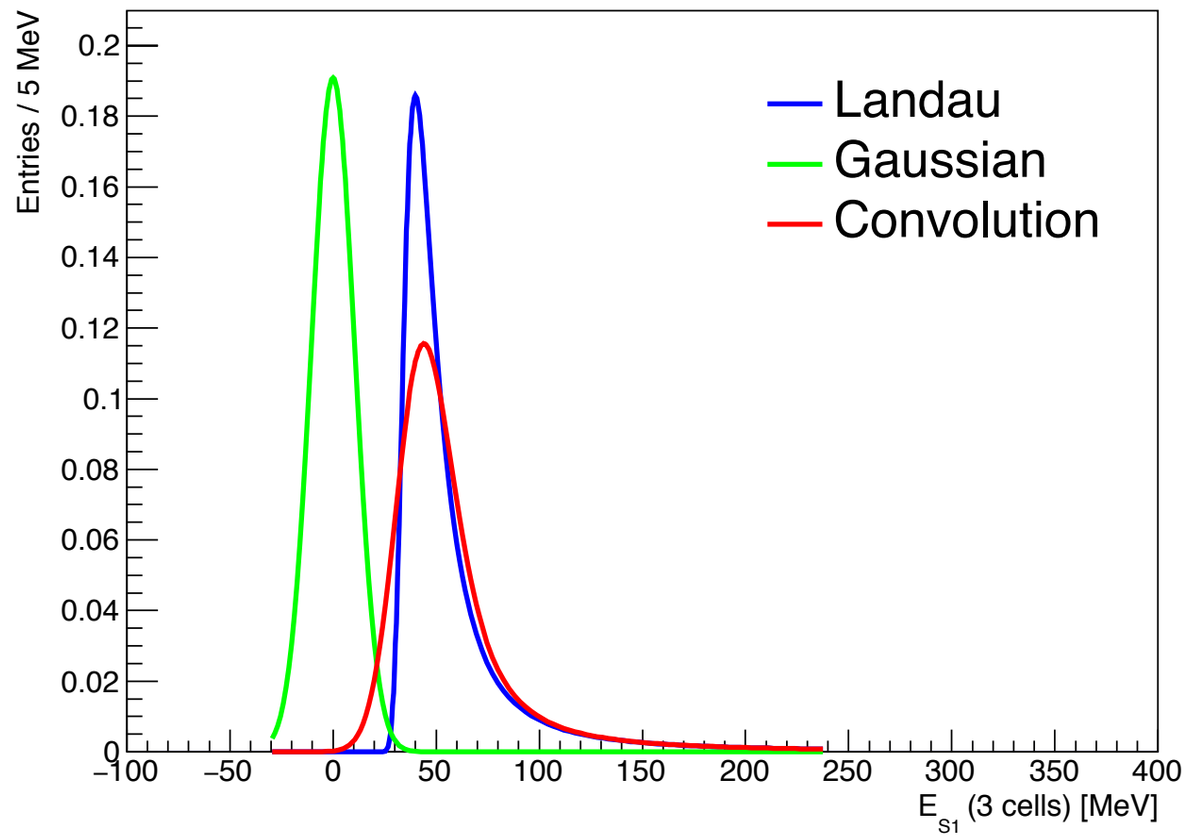


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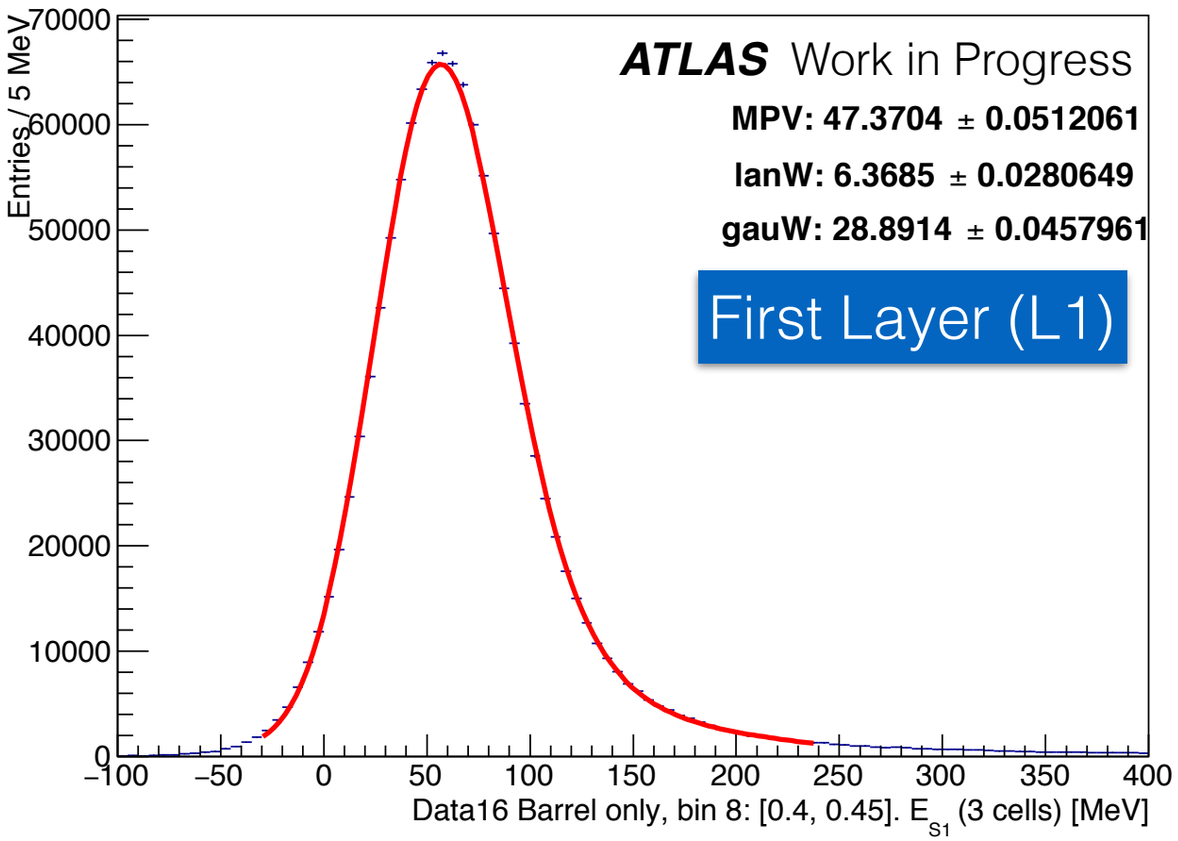
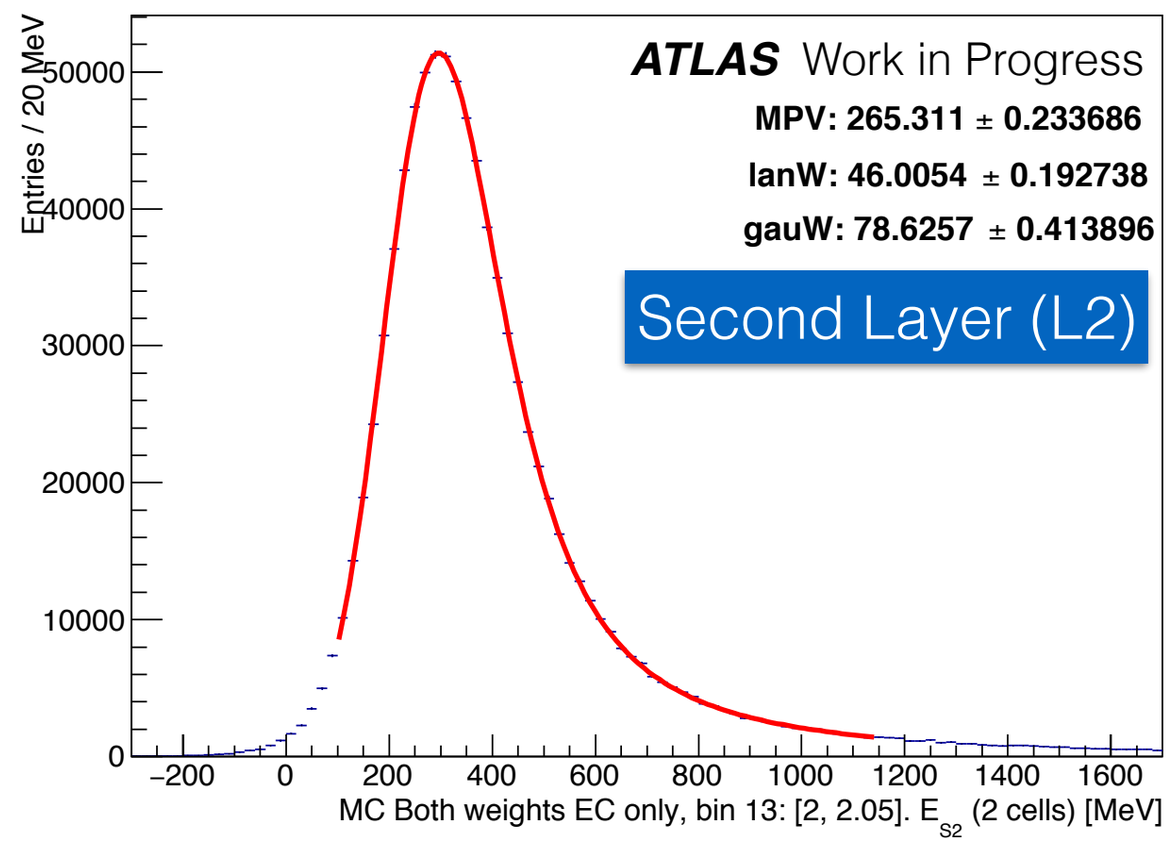
**Convo-lution!**

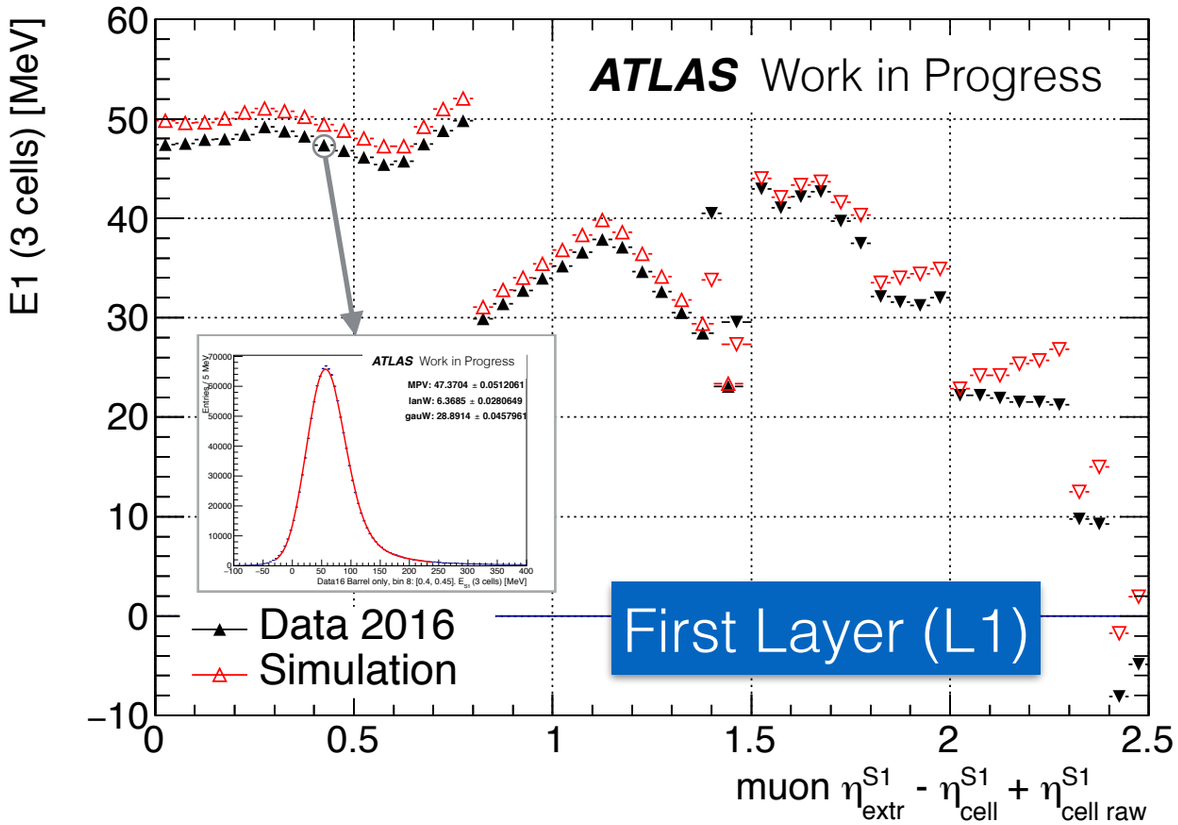
# What a nice fit!

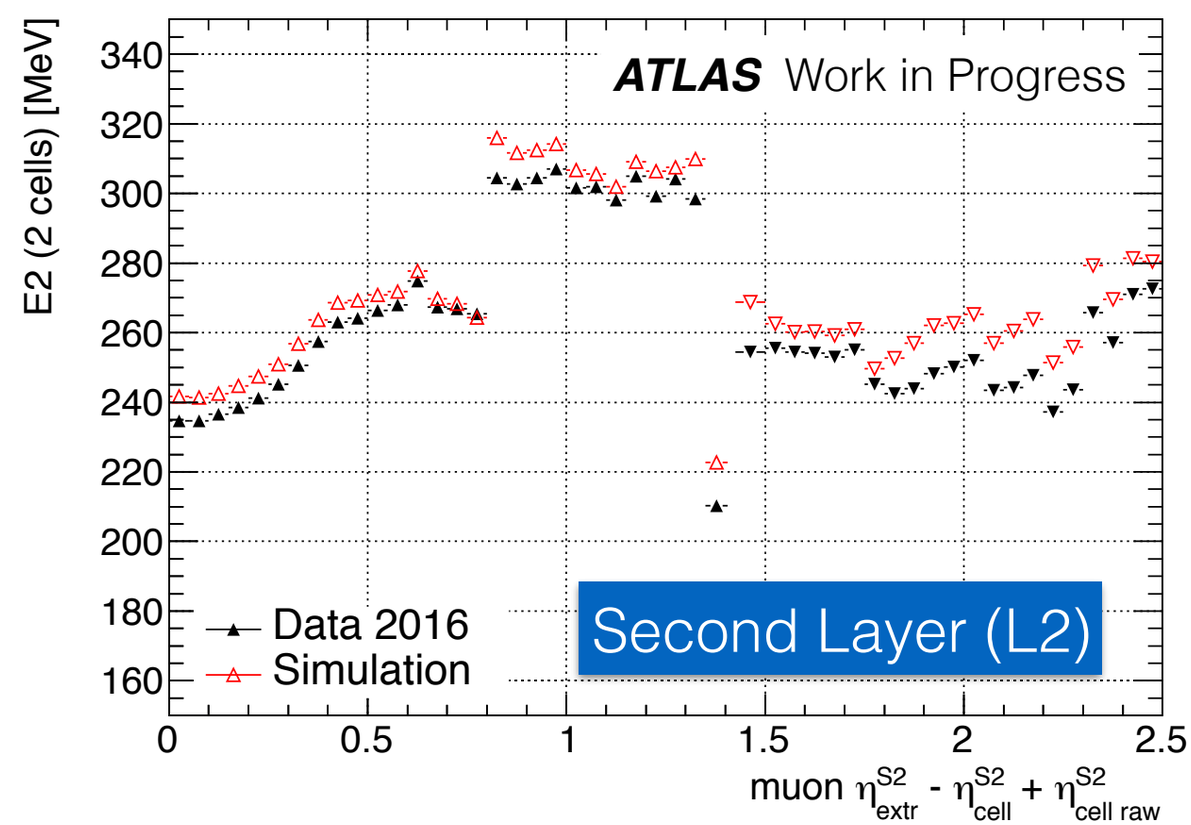



- Our **estimator of the muon energy deposit** is the **location of the peak of the underlying Landau** distribution ("**MPV**").
- Do it for every region of the detector, in S1 and S2, for Data and MC.

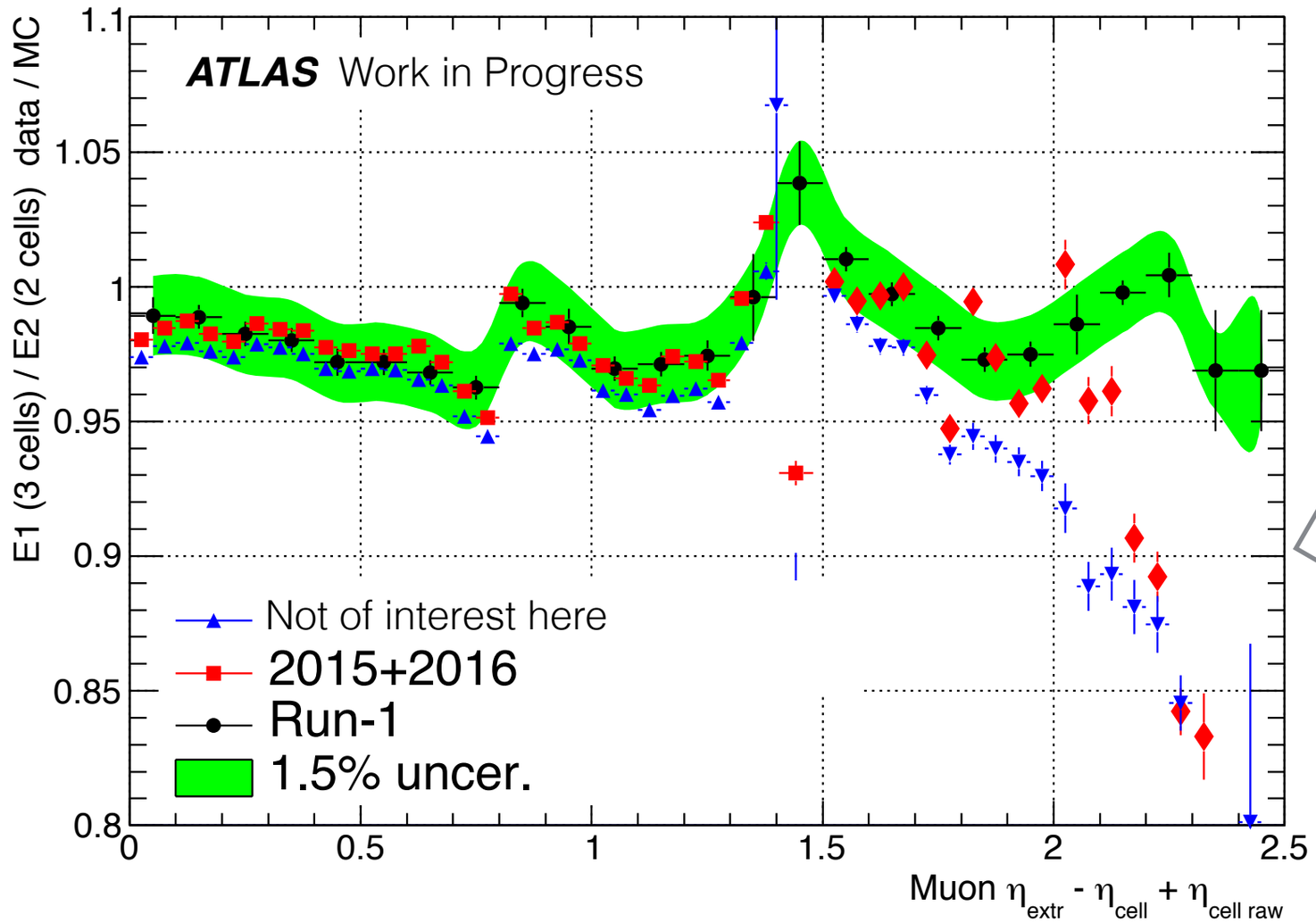
# Deposit as a function of the position




- **Each point here is the MPV of a fit** as shown previously.
- Small differences between data and MC… c'est la vie.
- Then we **take the double ratio** $\dfrac{E_1^{\mathrm{data}}/E_2^{\mathrm{data}}}{E_1^{\mathrm{MC}}/E_2^{\mathrm{MC}}}$

# Step 3: final result…




Forget about the blue points for now

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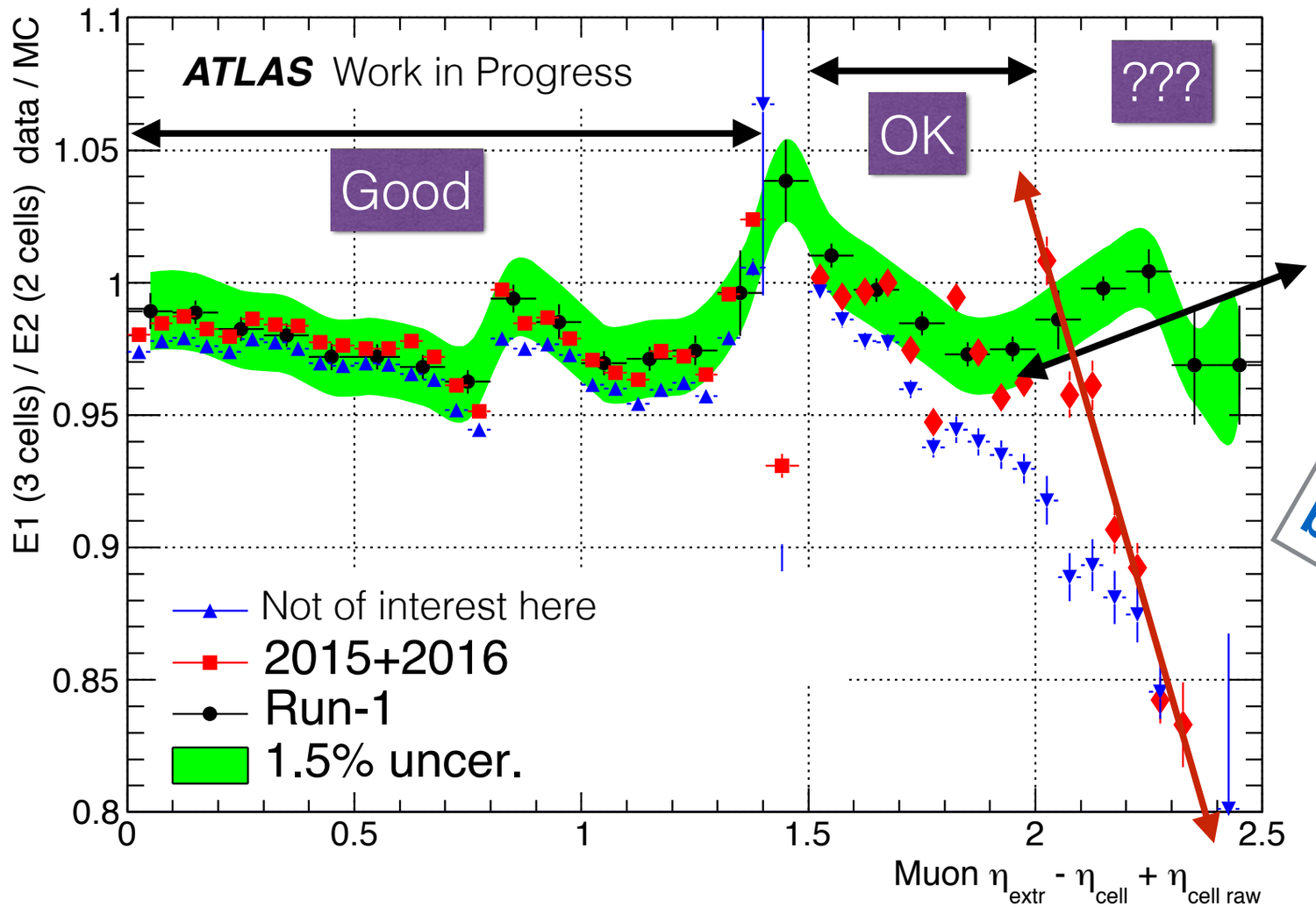


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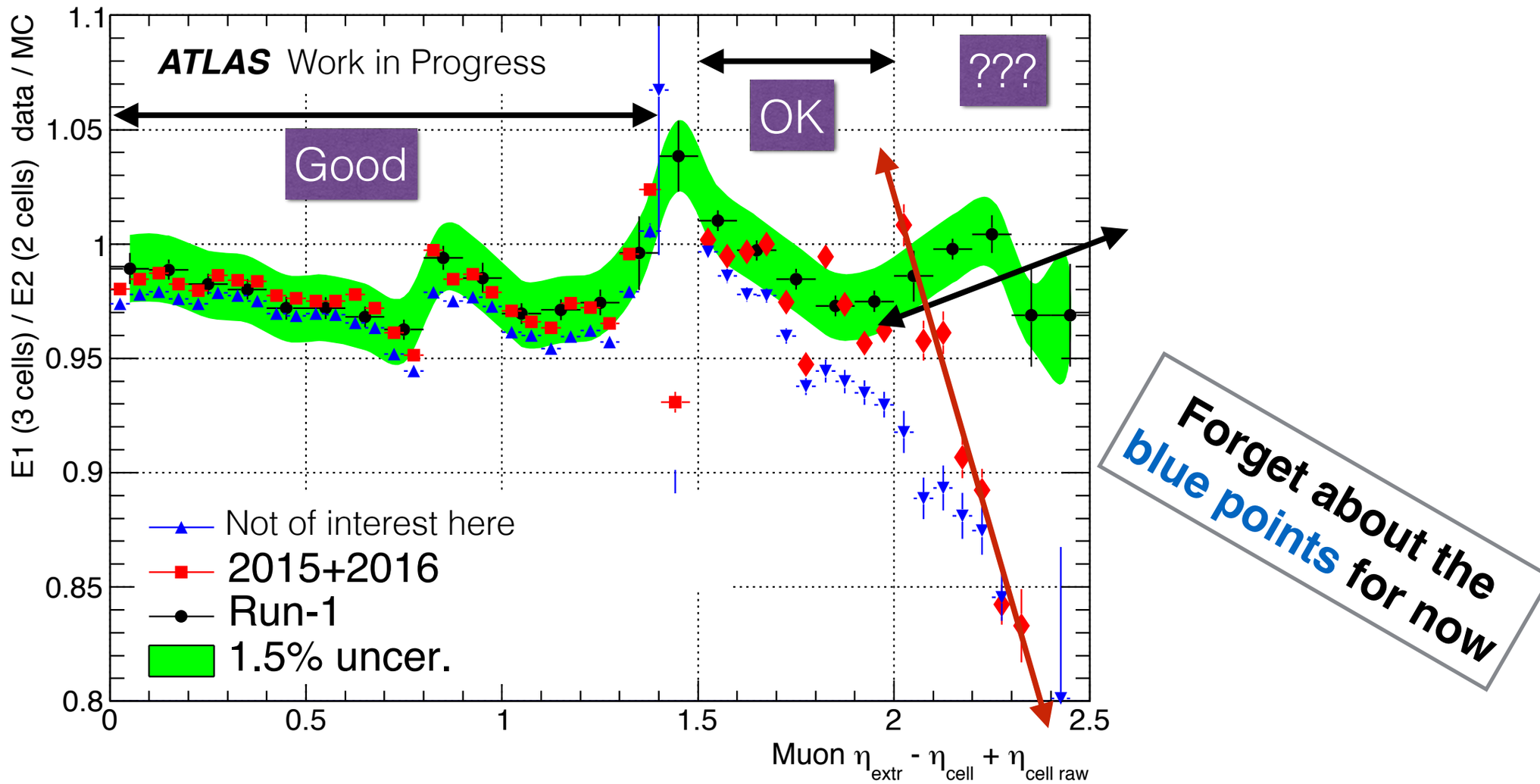


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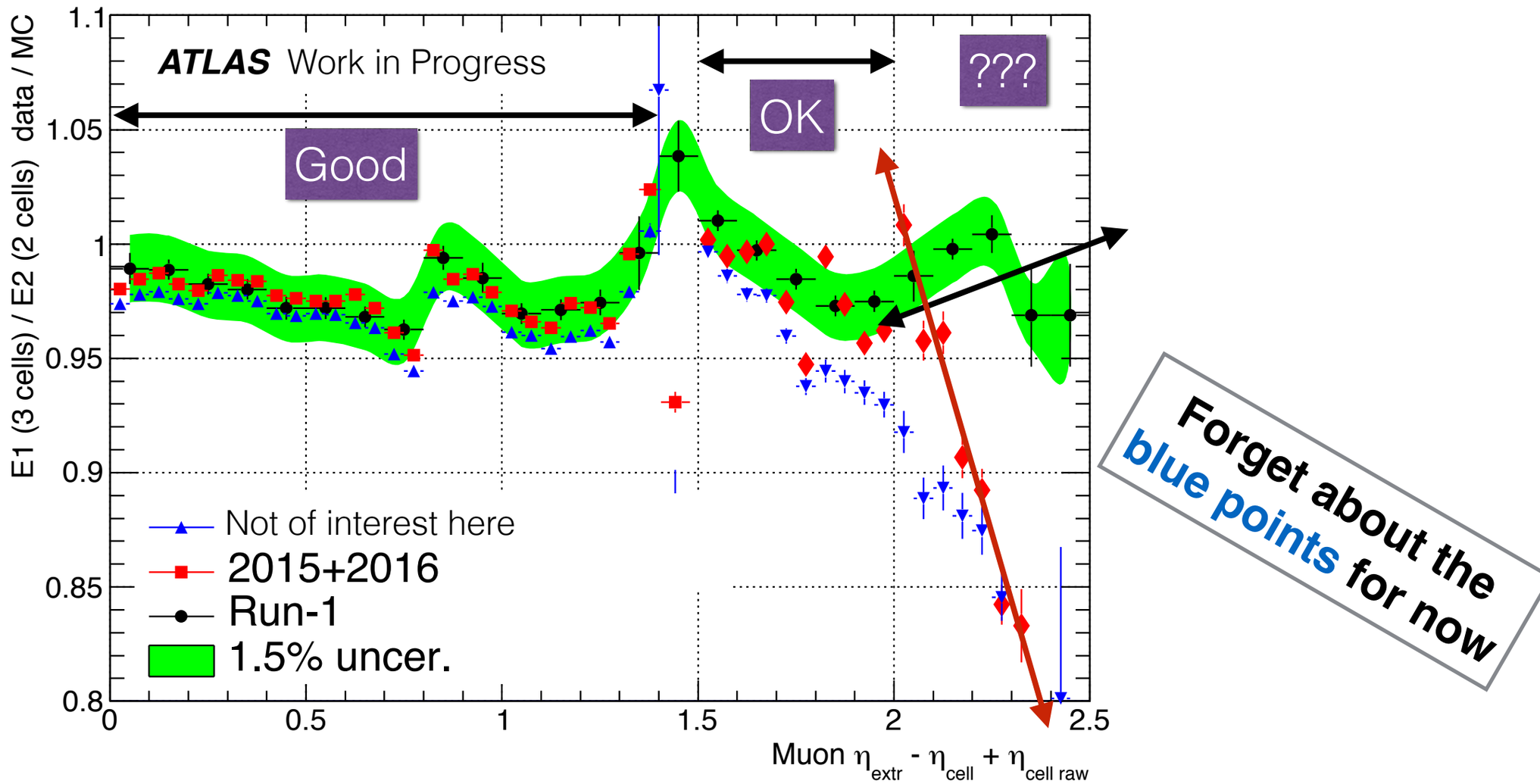


- **2016 result**: **agreement with 2012 ~OK in the central part** of the detector, **large difference in the far regions**.
- What is going on??? Could it be the pileup?

# A change in LHC conditions

- You said pileup? What's that?

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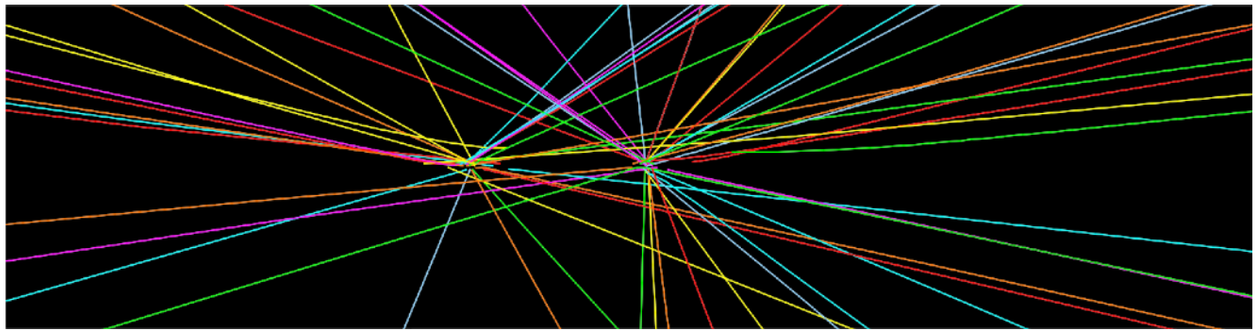
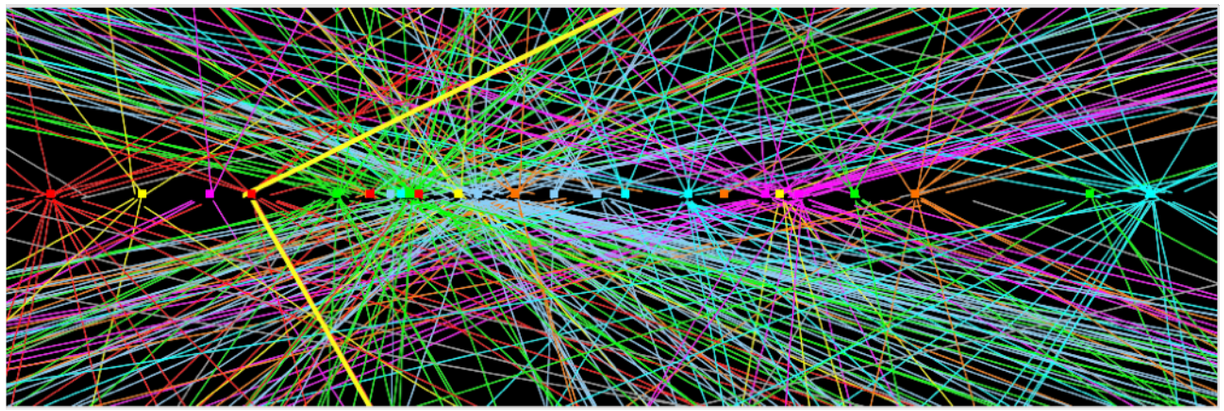


$<\mu> = 1$



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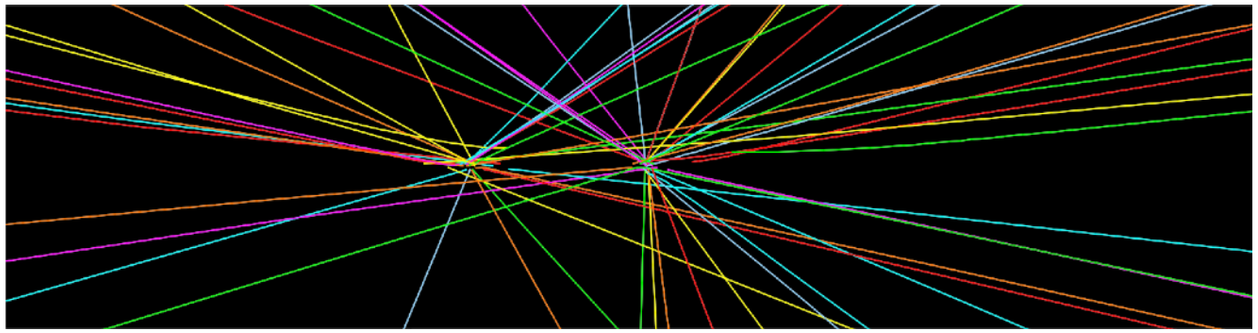

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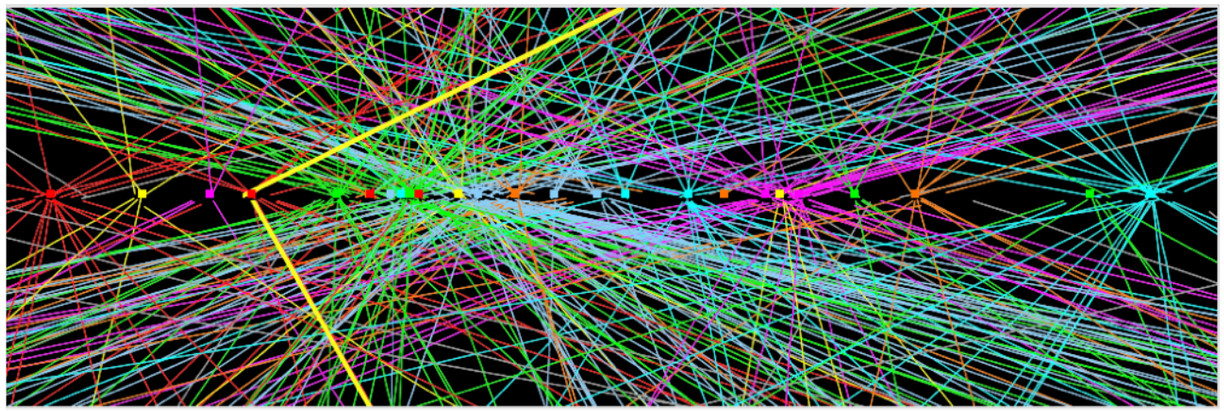

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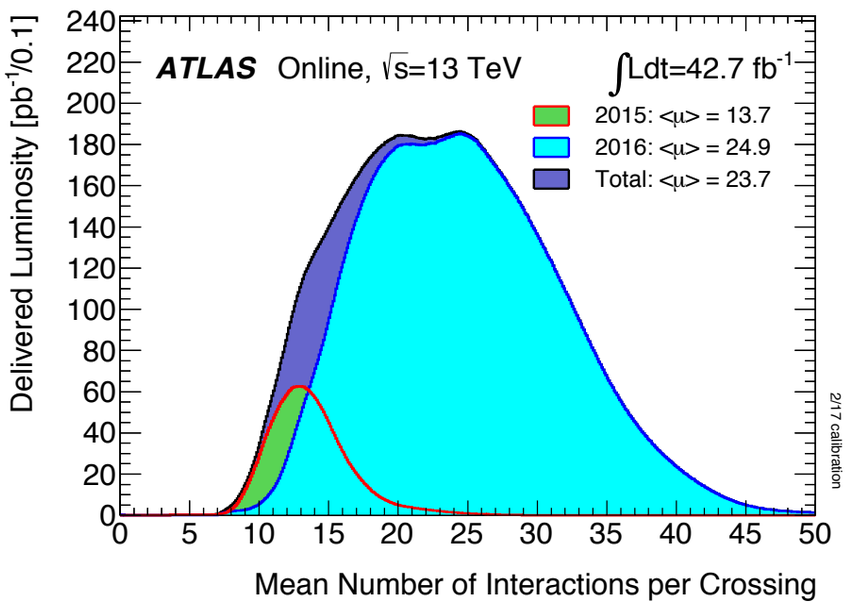


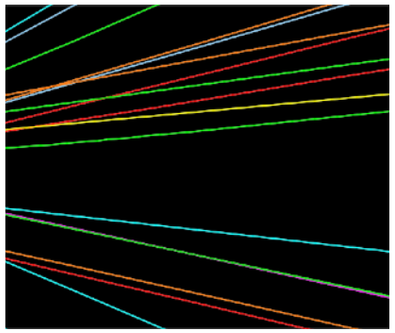

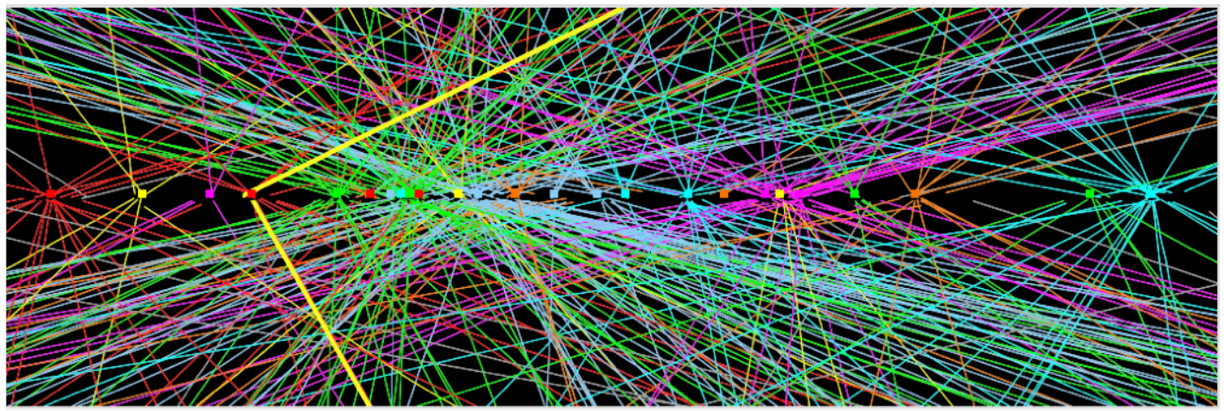

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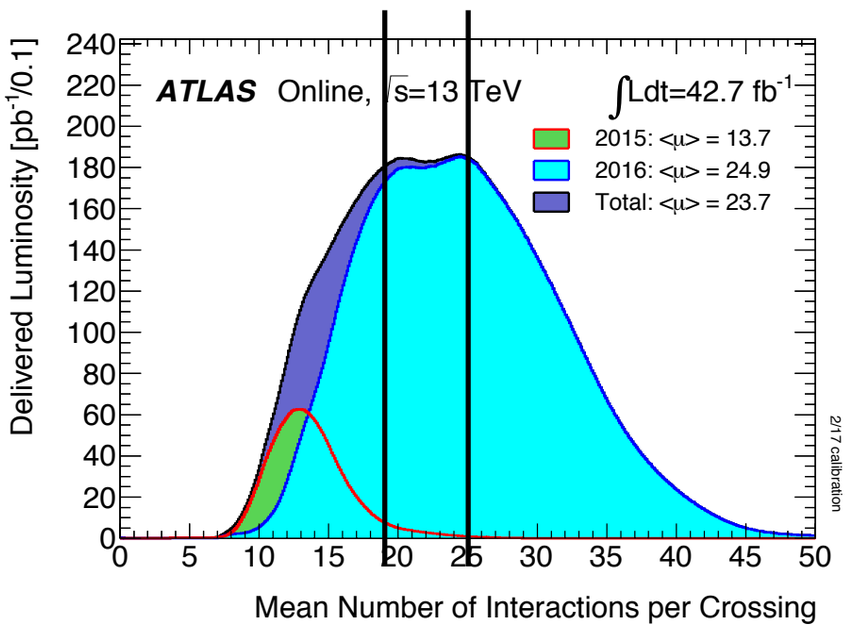
# So? Will the pileup confess?

- Inclusive → differential analysis: **split in pileup bins**.



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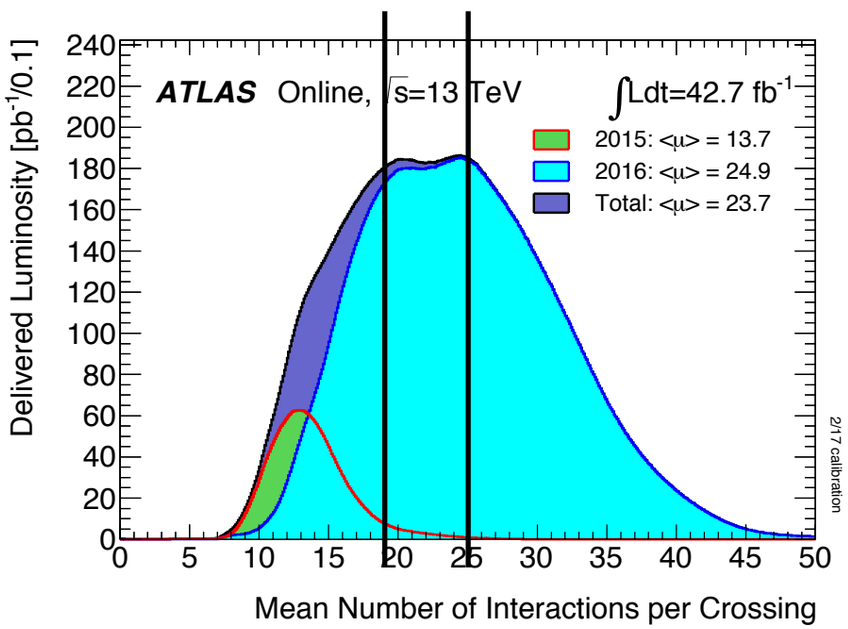


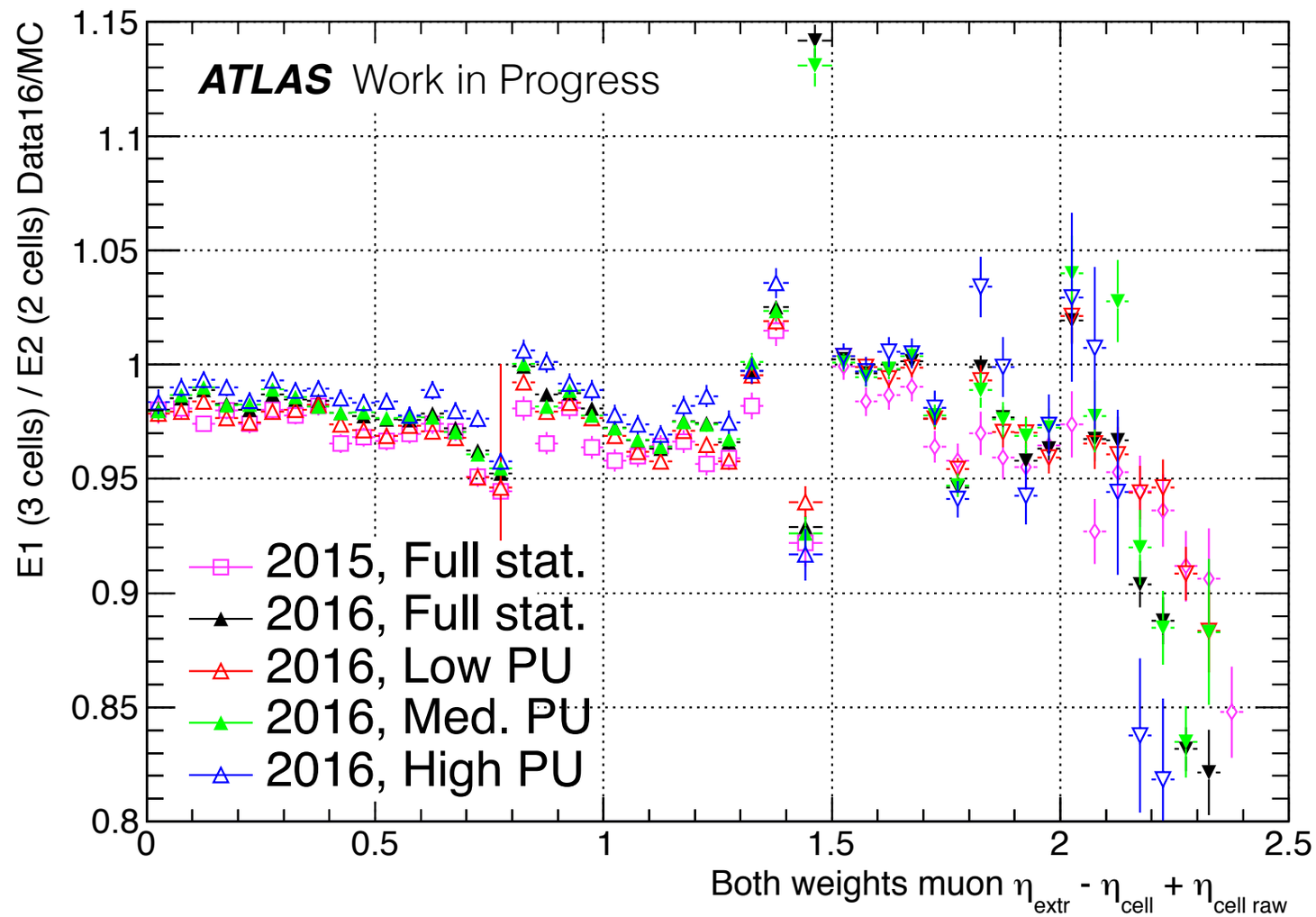

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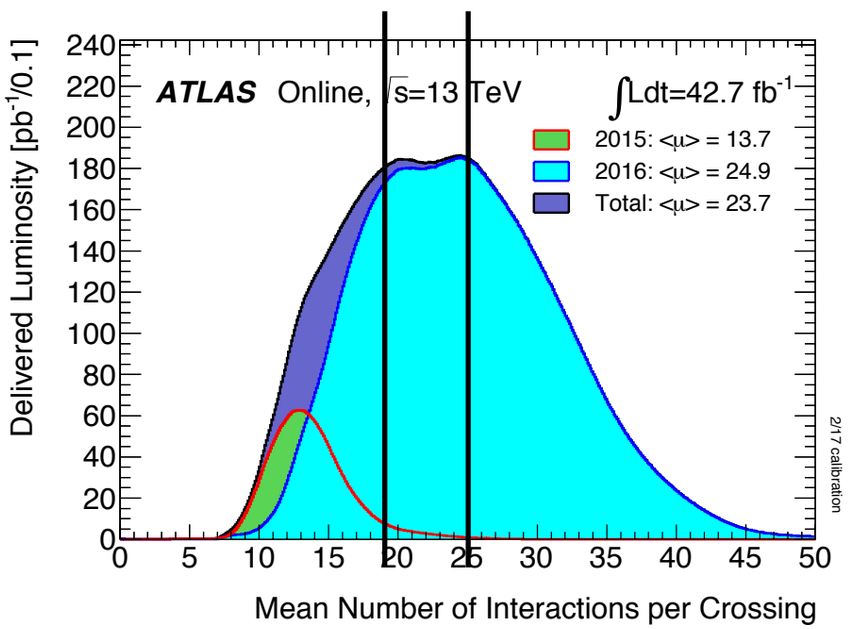
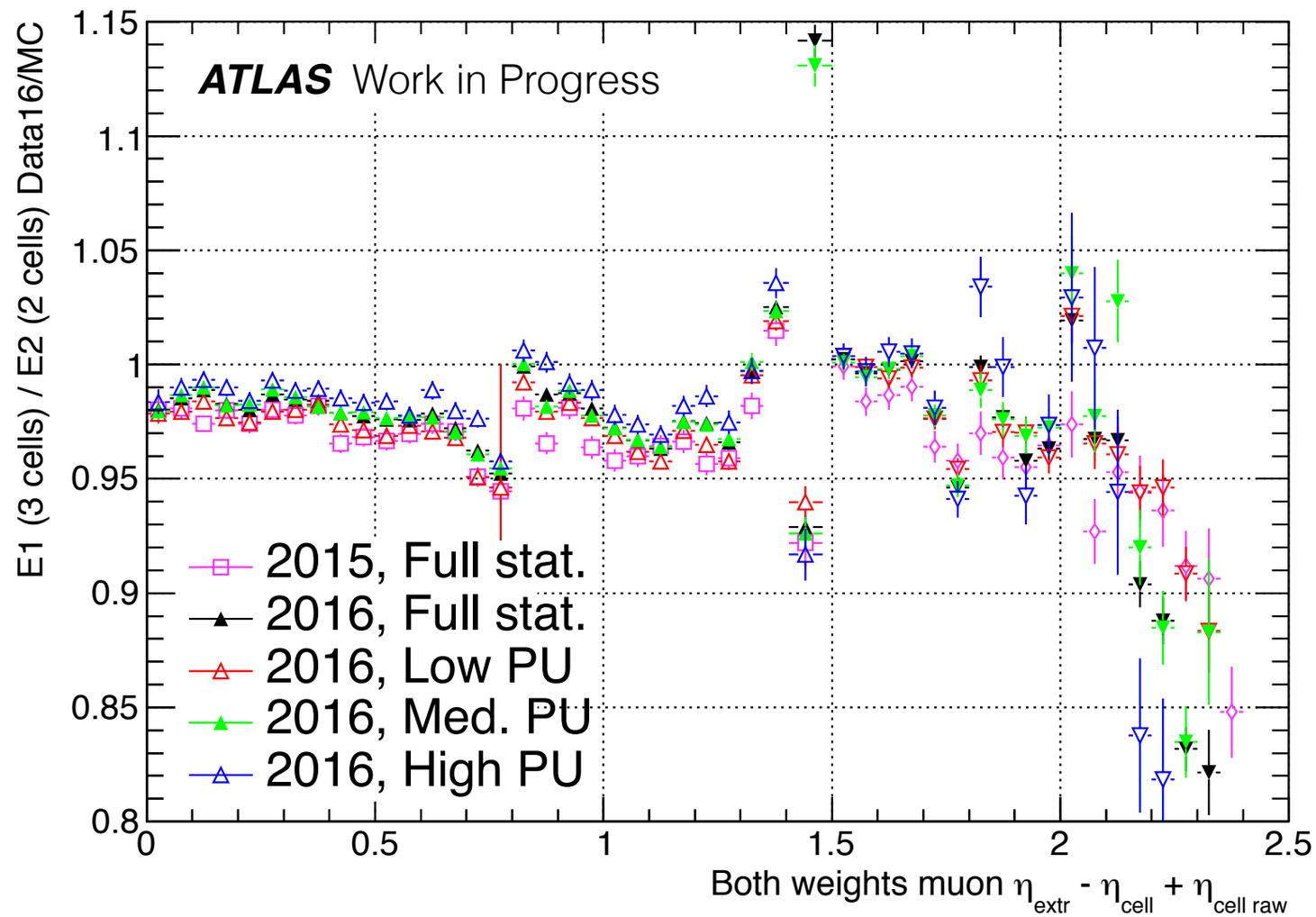
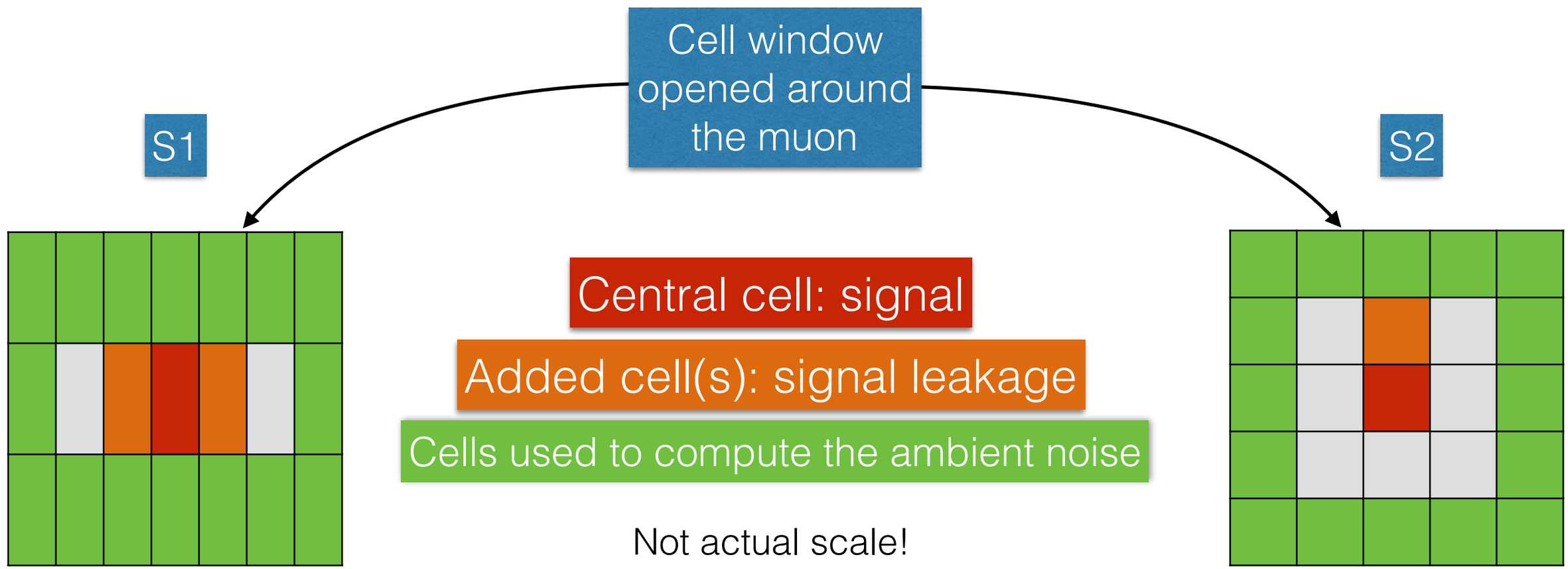



- Yes: **large differences in the various bins**.
- Then **how do we cancel** (or at least mitigate) **its effects**?

# Idea: subtract the ambient noise

- Try to **estimate the pileup contribution** by **looking at the energy in close by cells** not containing signal.



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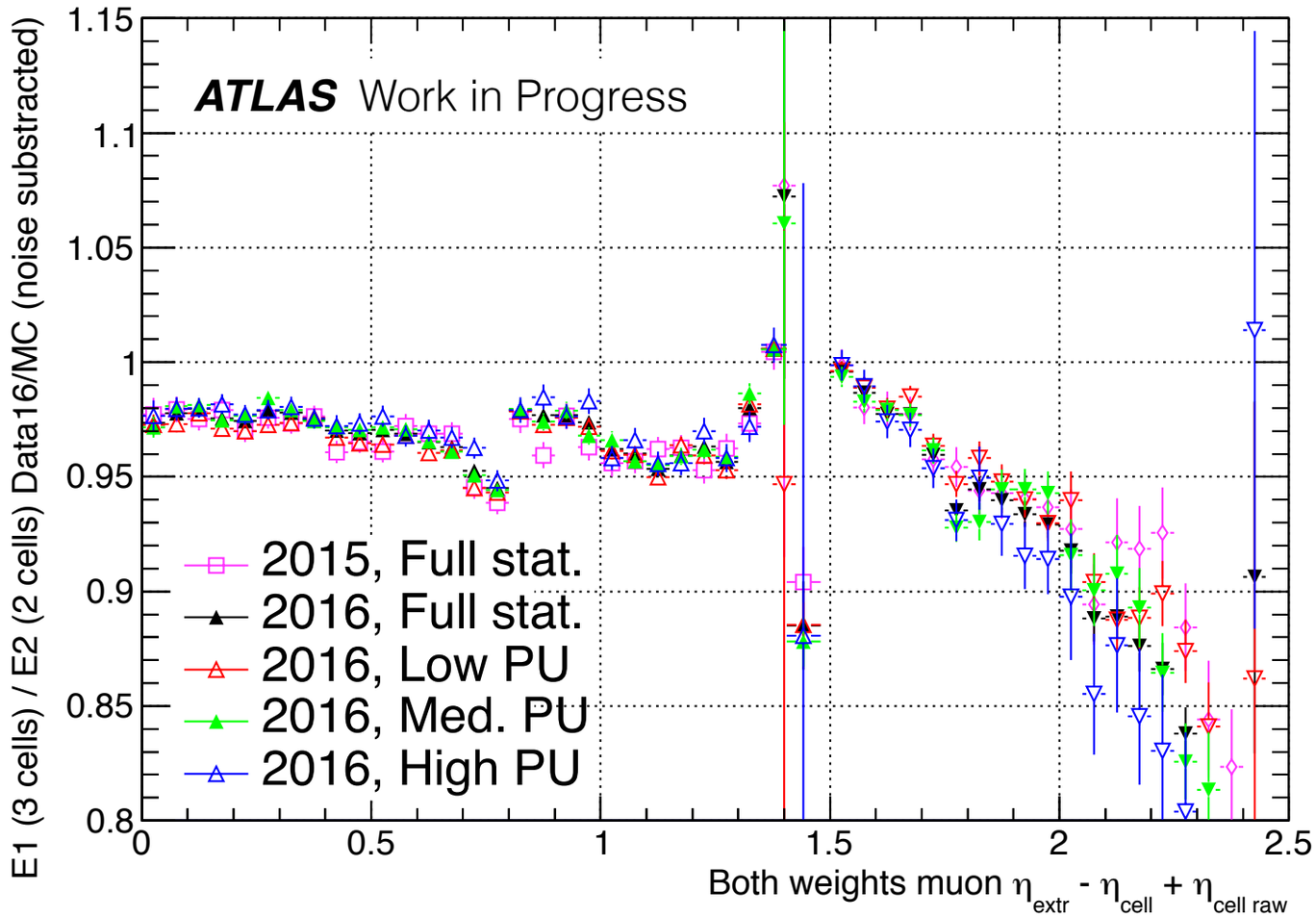


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- Tried a few other methods, which ended not working as well as needed either.

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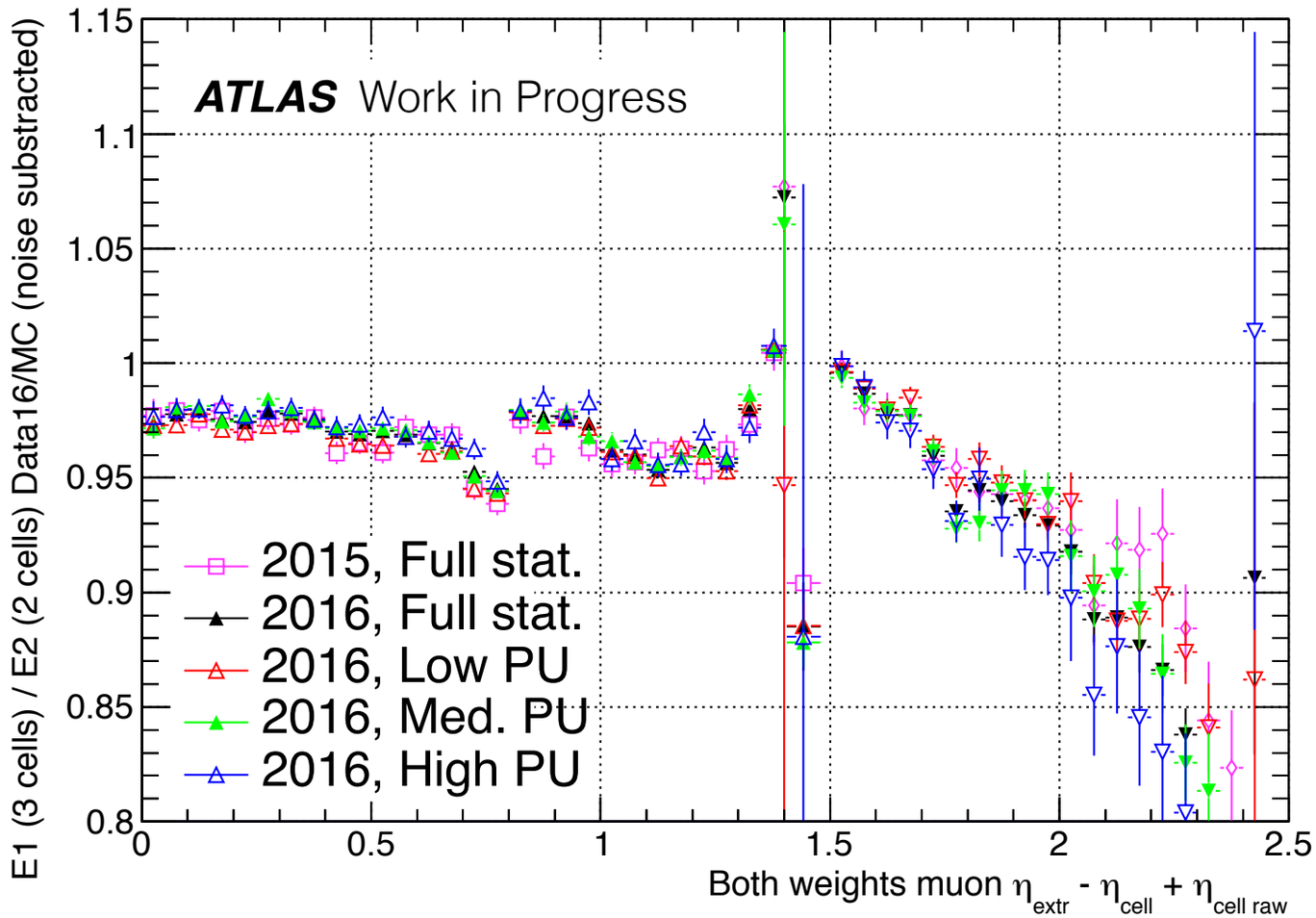


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- Tried a few other methods, which ended not working as well as needed either.
- So **what can we do?** Panic?

ATLAS EXPERIMENT

# KEEP CALM AND THINK OF NEW IDEAS

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- In other words: **why don't we take samples without pileup?**

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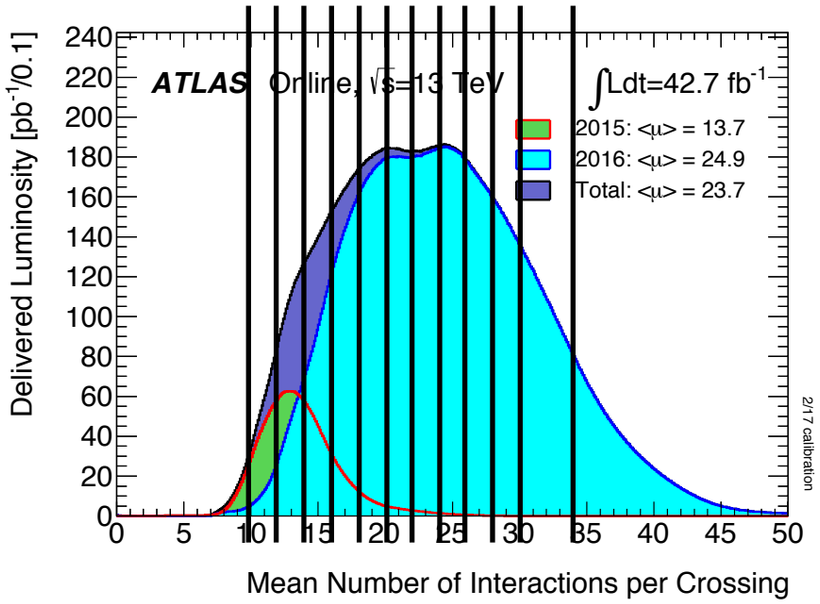
- So **how can we build/simulate a "pileup-less" sample from the data**?
- Let's use the most powerful tool we have: **extrapolation**.

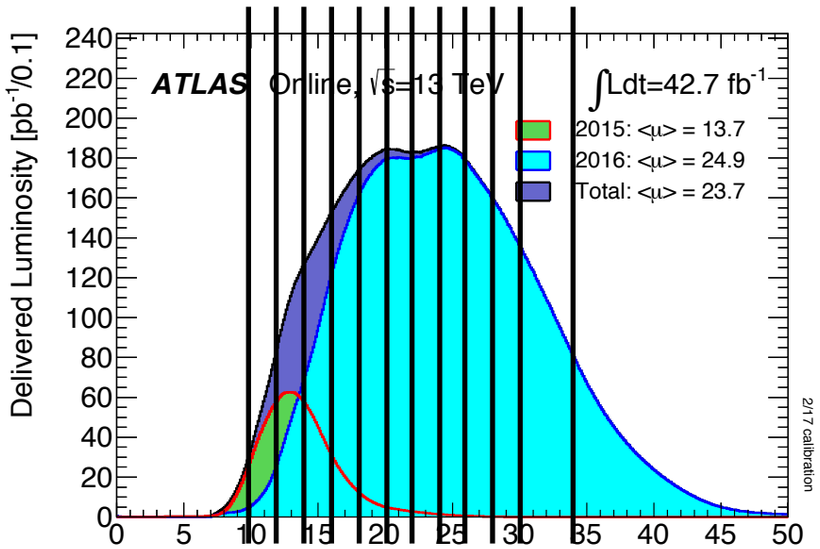
# Extrapolation to $<\mu> = 0$

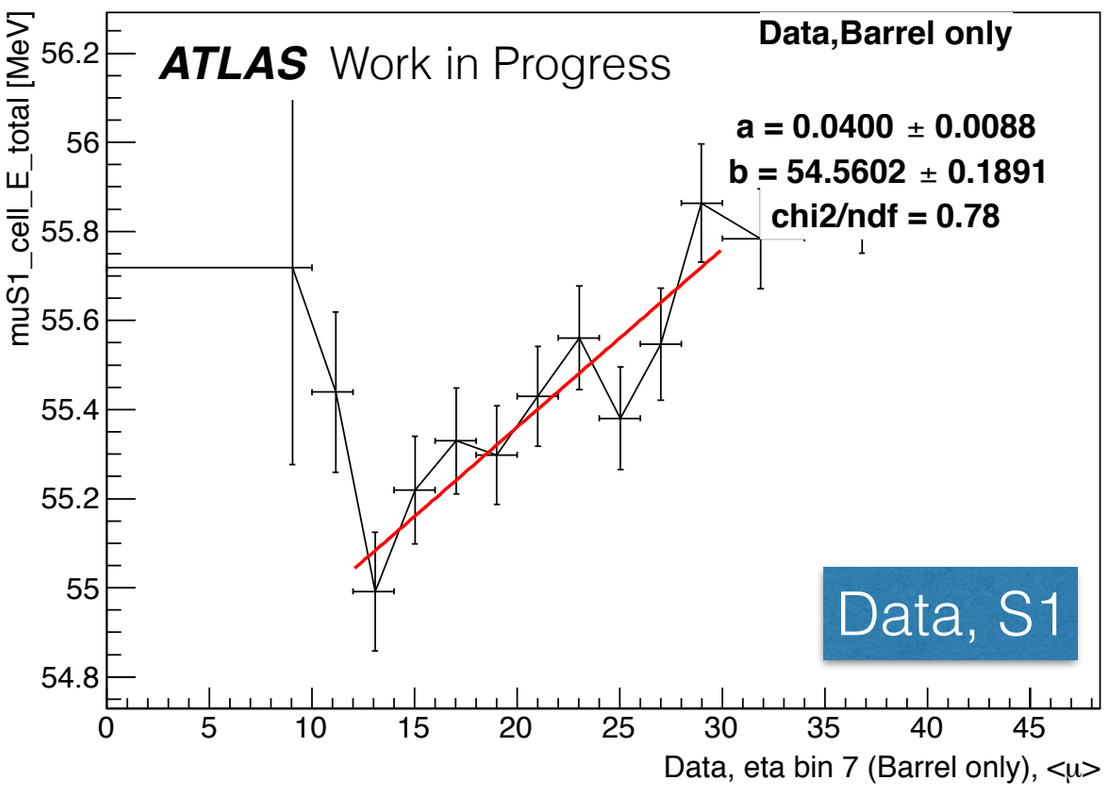
- **Split the dataset in 13 pileup regions** (instead of 3 previously).

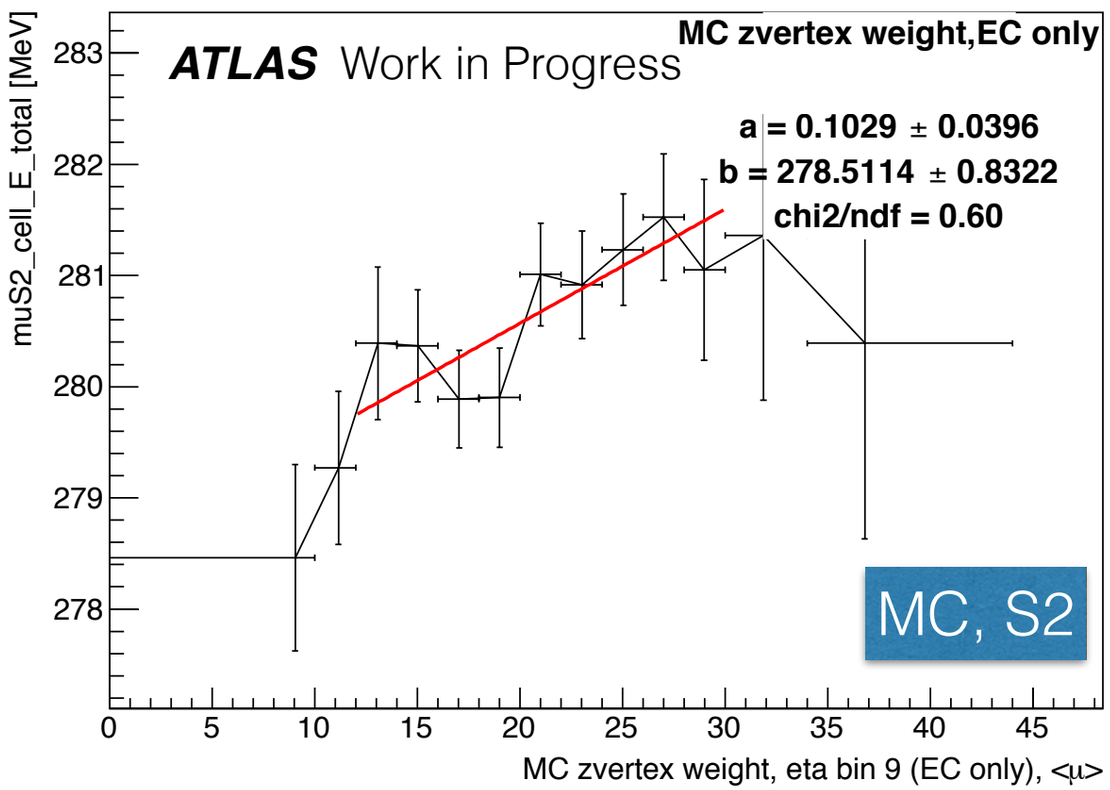


# Extrapolation to $<\mu> = 0$

- **Split the dataset in 13 pileup regions** (instead of 3 previously).
- **For each bin of pileup in each region of the detector, do the Landau⊗Gaussian fit.**

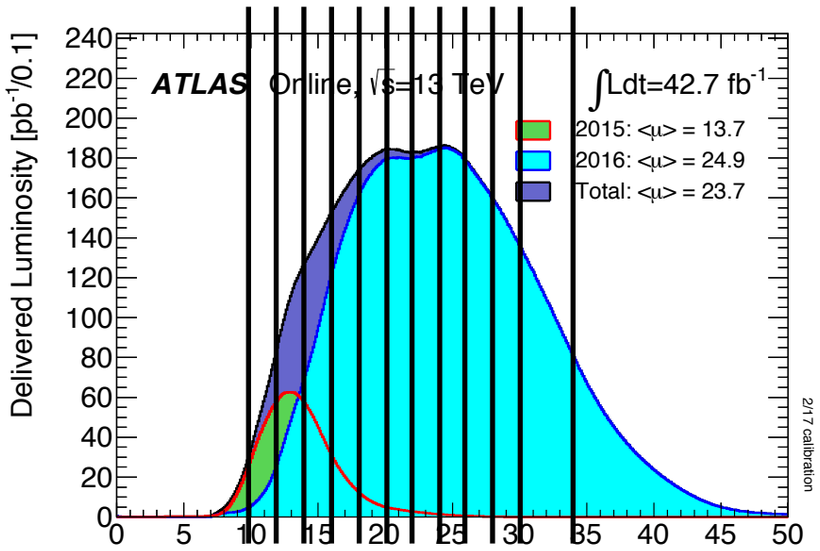


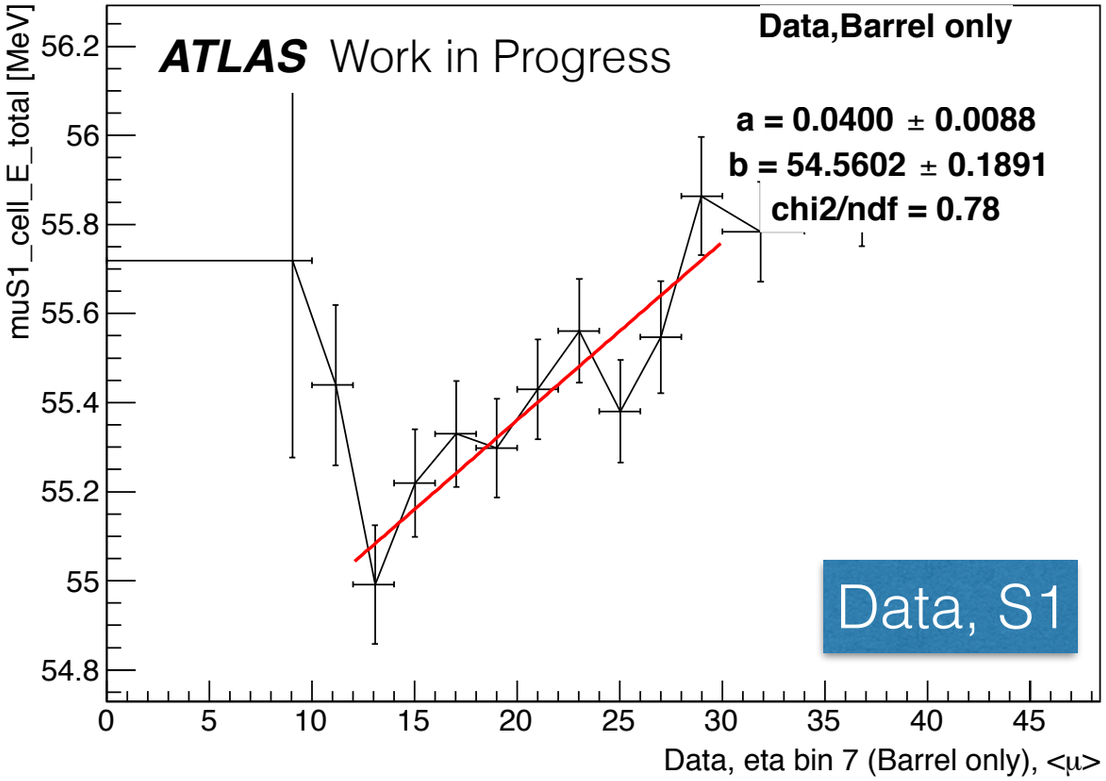



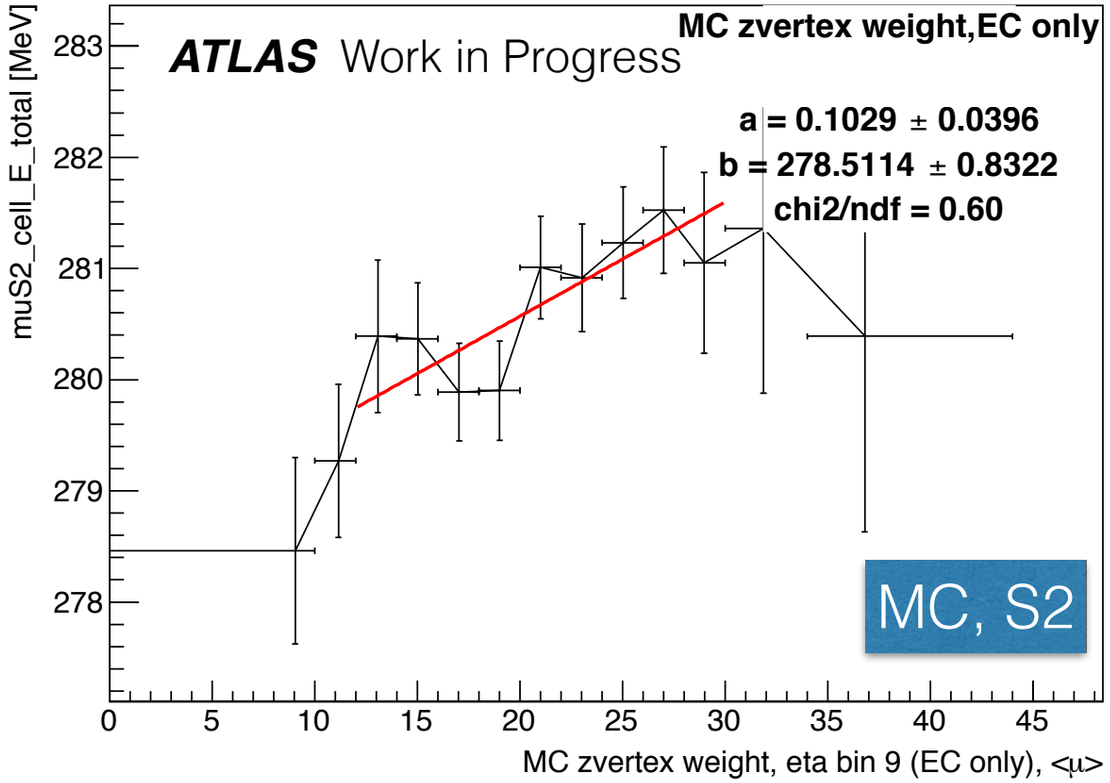



# Extrapolation to $<\mu> = 0$

- **Split the dataset in 13 pileup regions** (instead of 3 previously).
- **For each bin of pileup in each region of the detector, do the Landau⊗Gaussian fit.**
- **In each detector region, perform a linear fit of the muon energy deposit MPV** across the pileup bins.



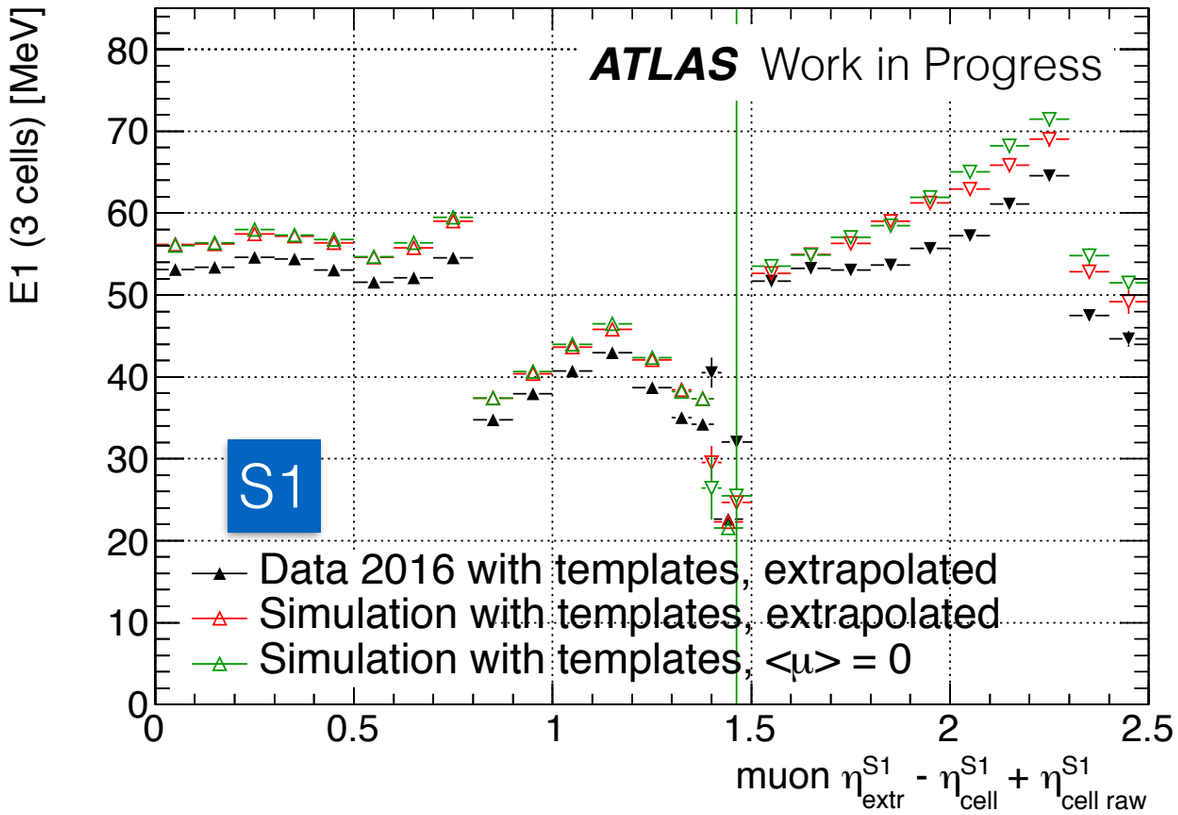



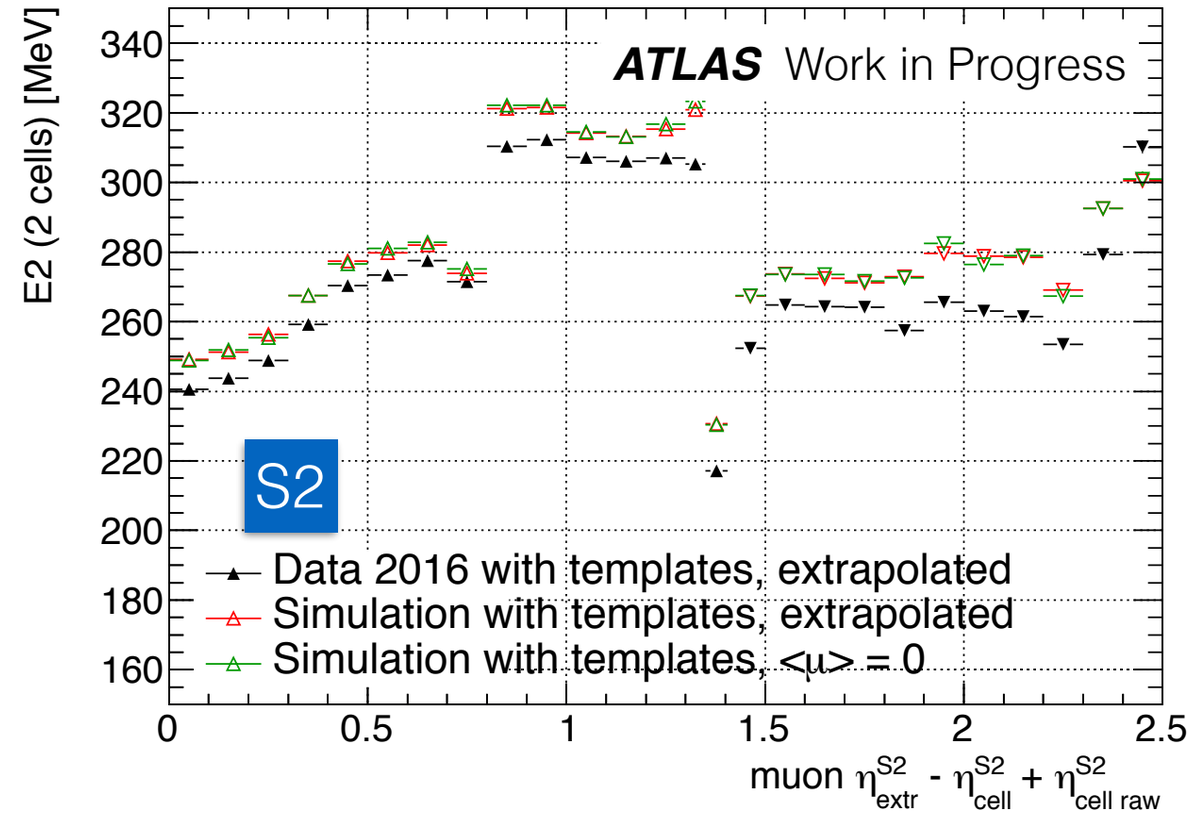



# Are you sure it really works?

- **Still need to validate the method** ("closure test").
- How?
  - **produce a simulated sample without pileup**,
  - check that the **extrapolation in the simulation** and the **simulation without pileup** give the **same result**.

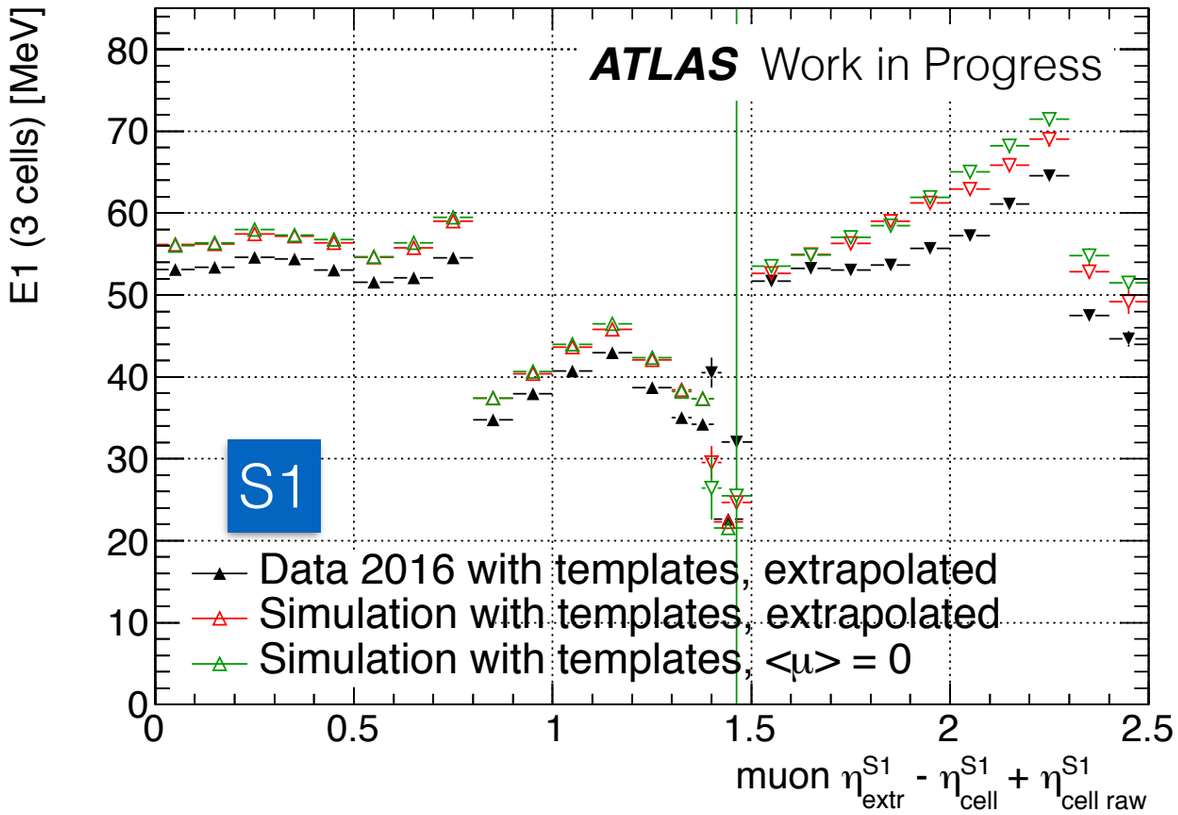
# Which leads to…

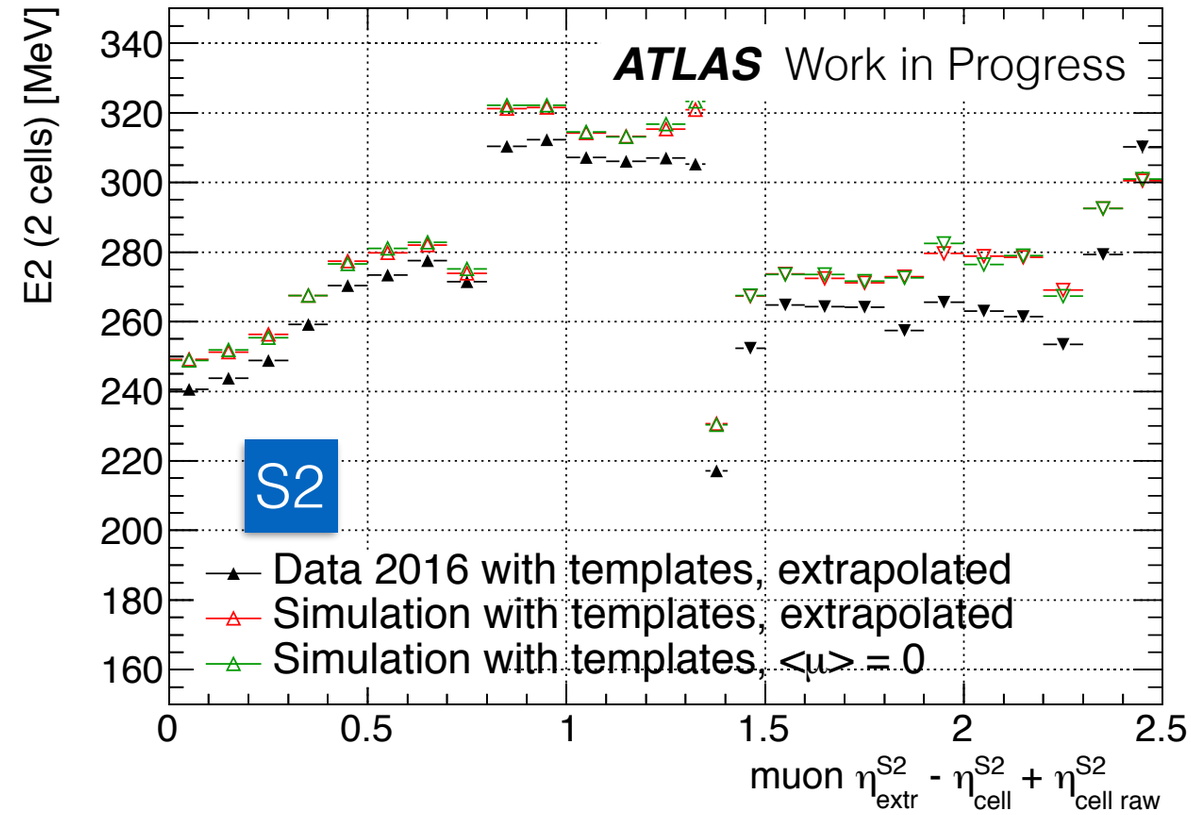



- Happy if **red** and **green** **match**.

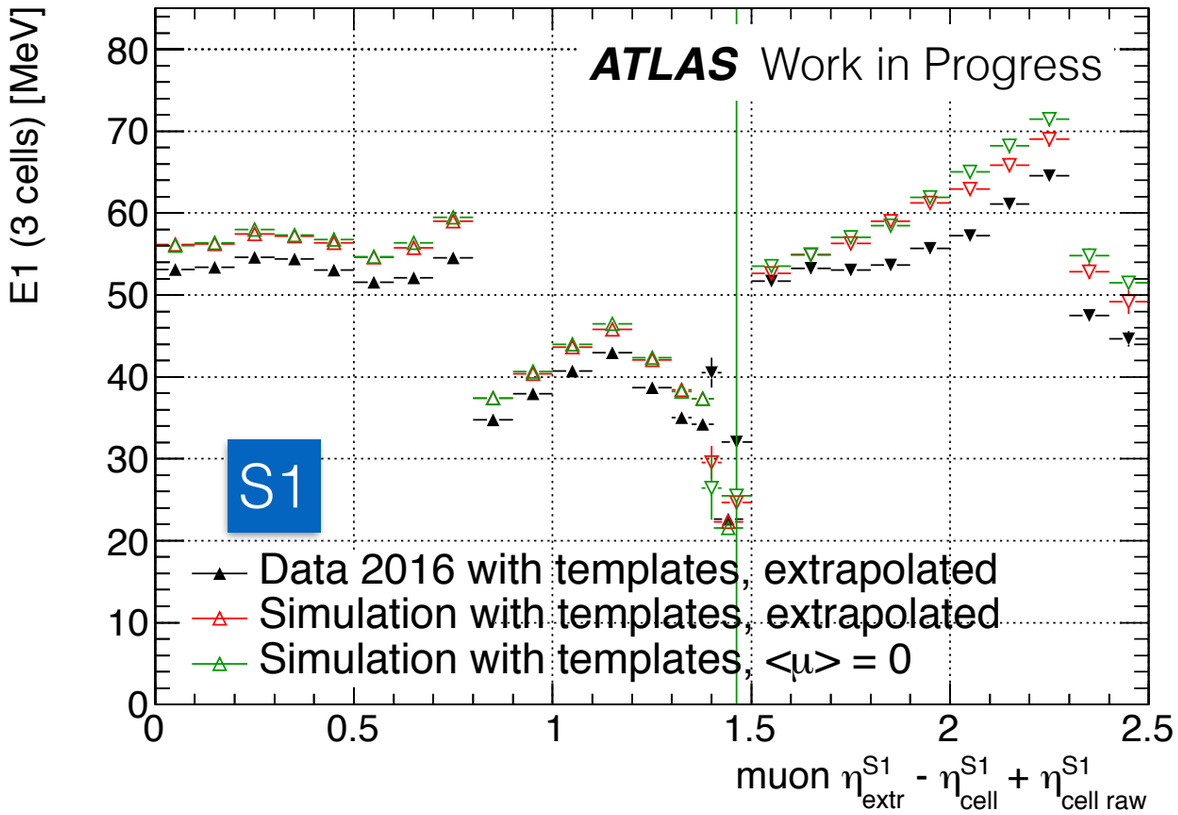
# Which leads to…

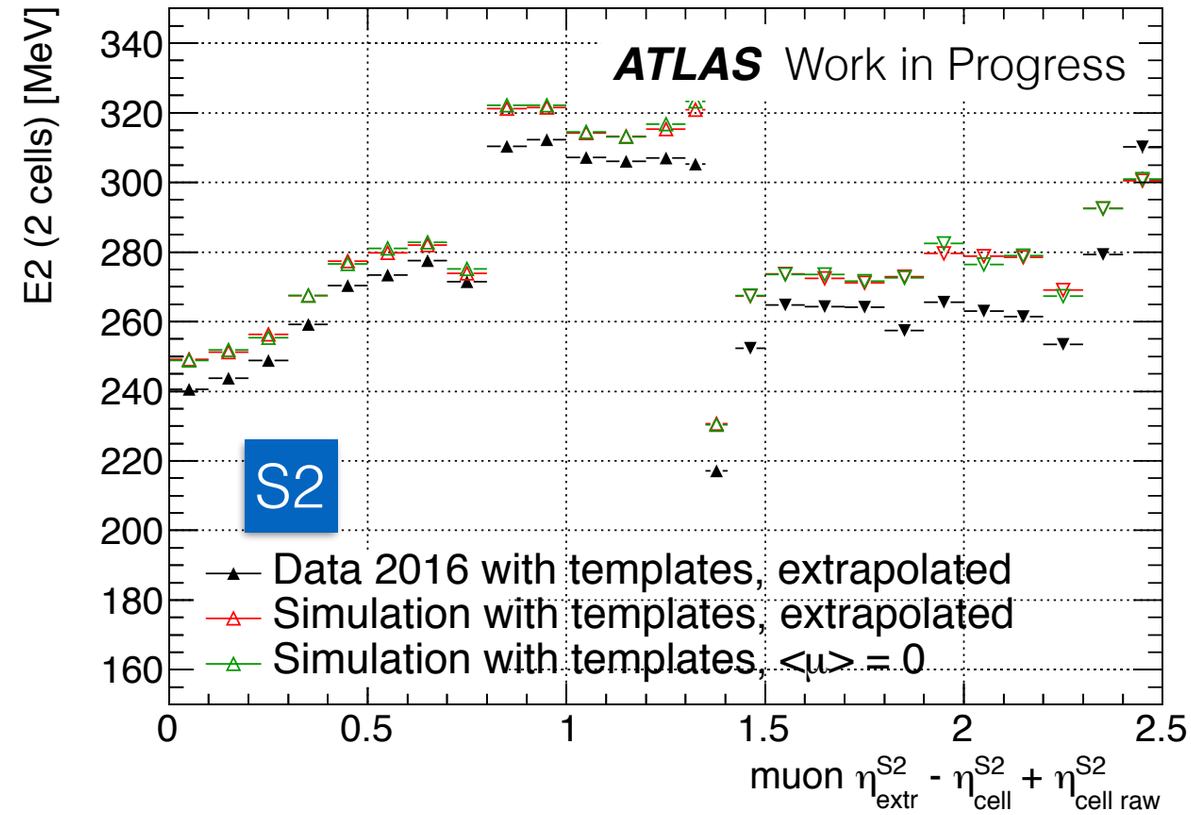



- Happy if **red** and **green match**.
- **Fair agreement**, difference taken as a systematic on the result.

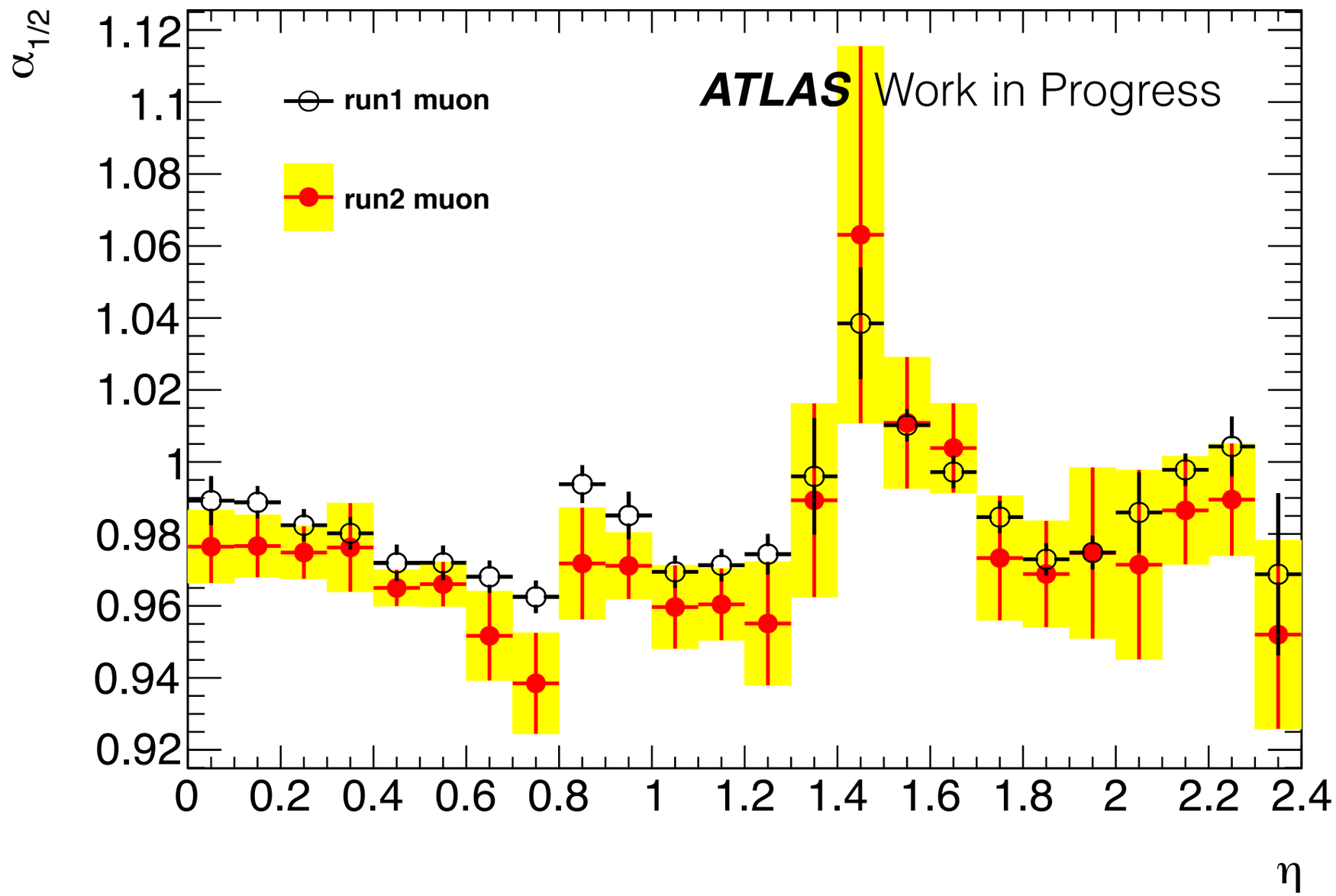
# Which leads to…




- Happy if **red** and **green** **match**.
- **Fair agreement**, difference taken as a systematic on the result.
- Also changed the noise model from Gaussian to a template, improving the closure.

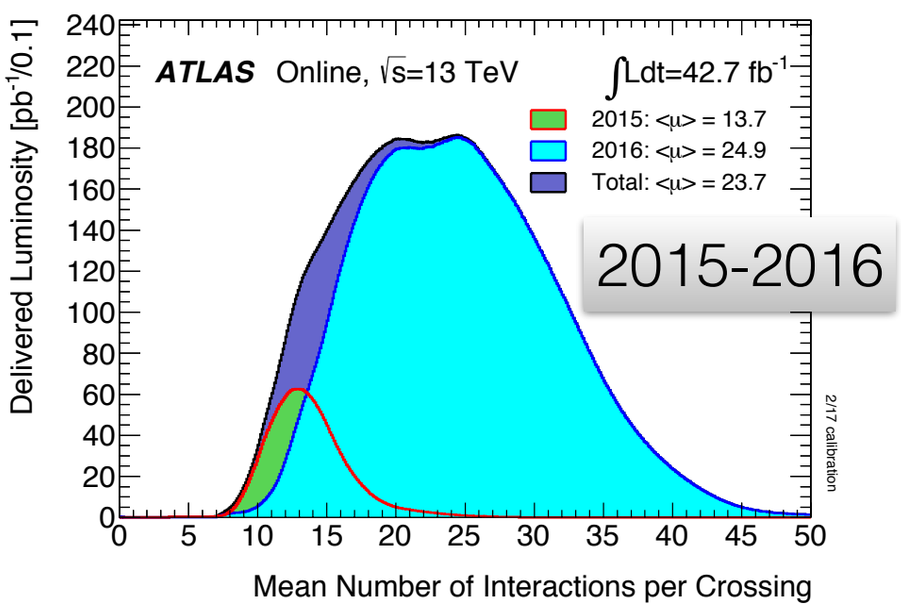
# Final result

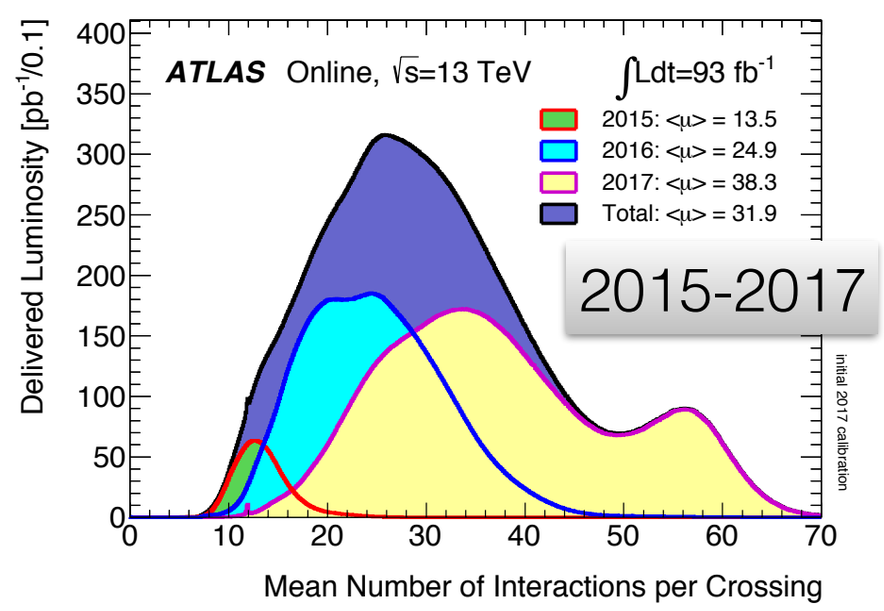



- **1-2% difference with 2012** result, but **same behaviour** ("no fall").
- **Works!**

# Conclusion

- **Analysis finalised** with all its systematics, paper detailing all the calibration process being written.
- Third layer not mentioned here: some work still ahead.
- Some **LHC runs in 2017 and 2018 with very low pileup** will **help validating the extrapolation** in the data as well.
- **2017 dataset is now included as well** (2018 data being recorded now!), but with **much higher pileup**.

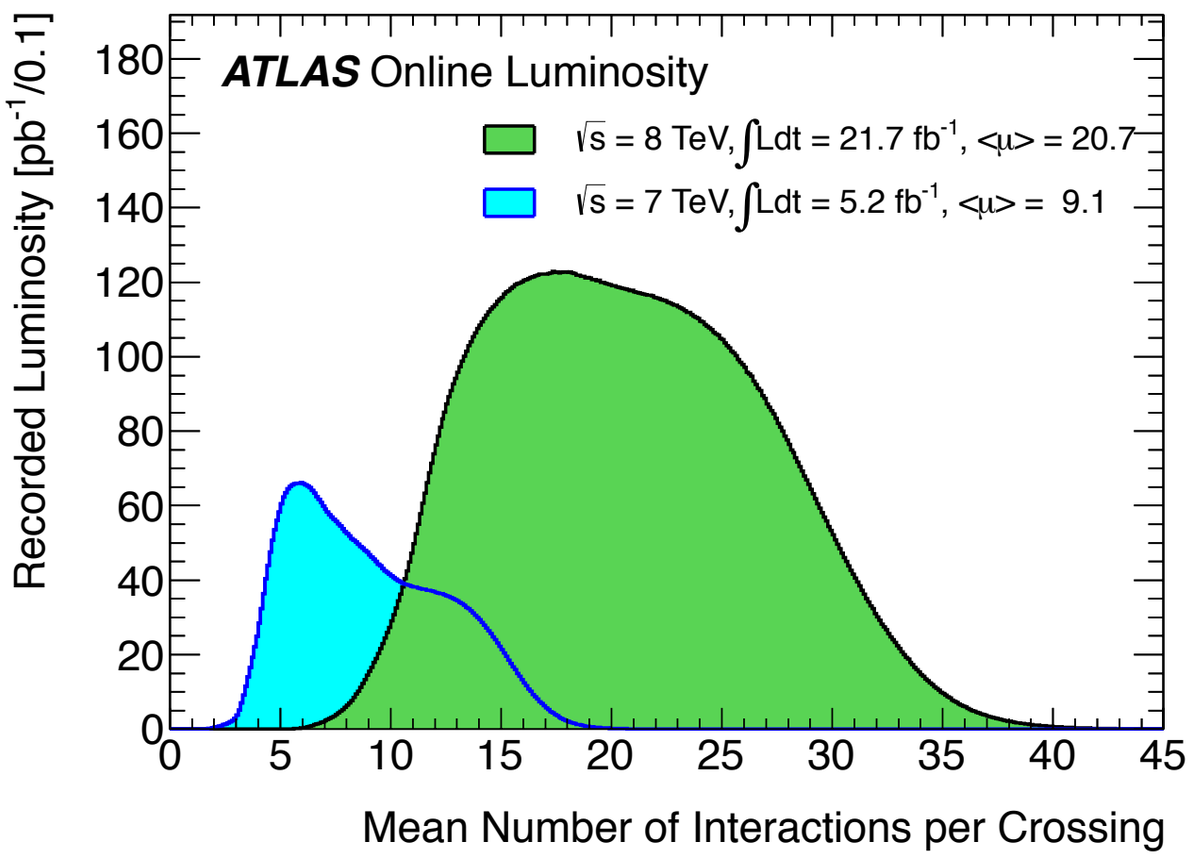


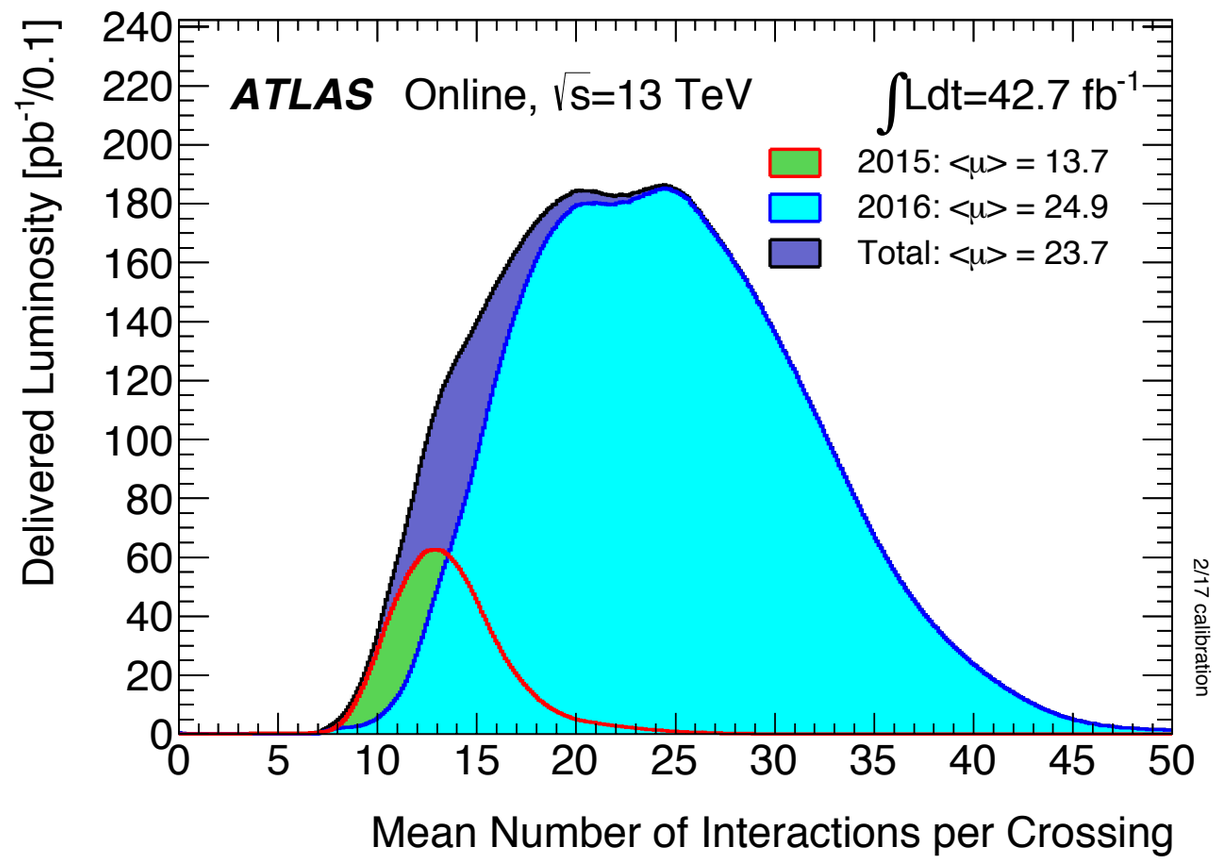
# *BACKUP*

# Why no issue seen in Run-1?

2011-2012



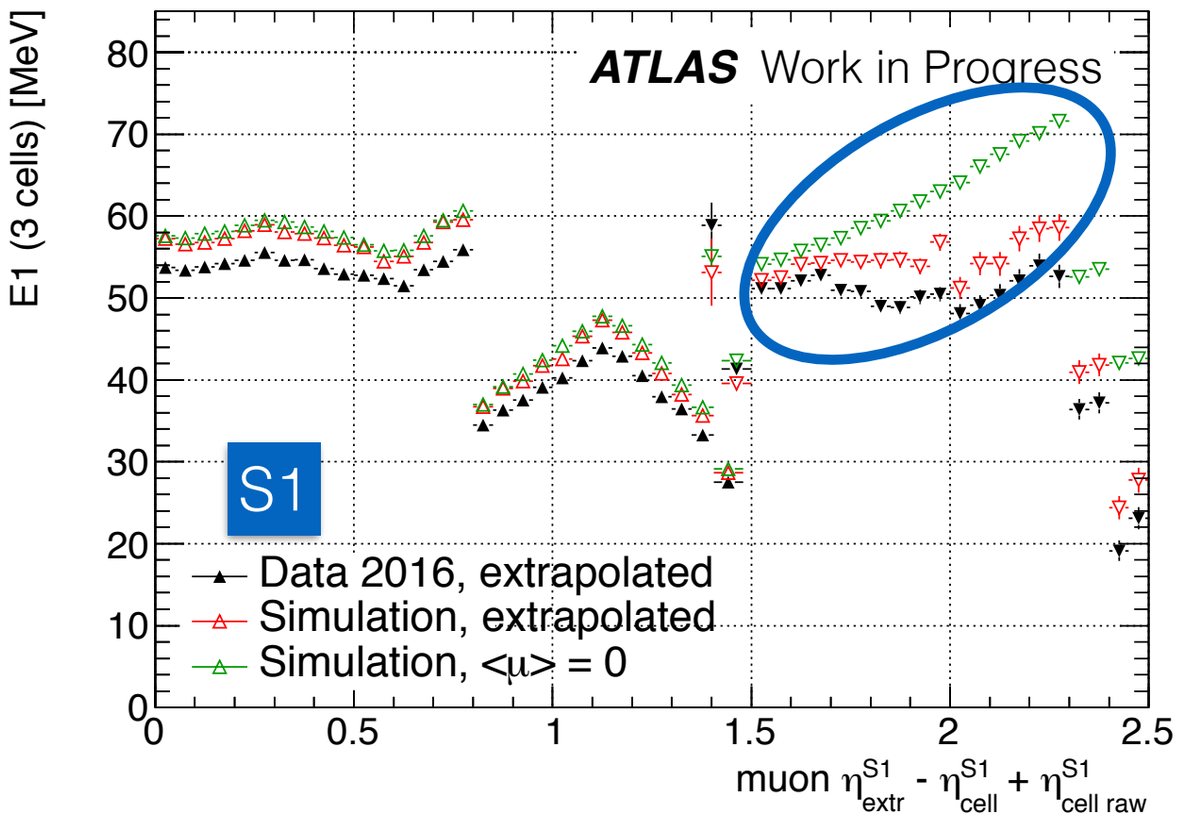

2015-2016

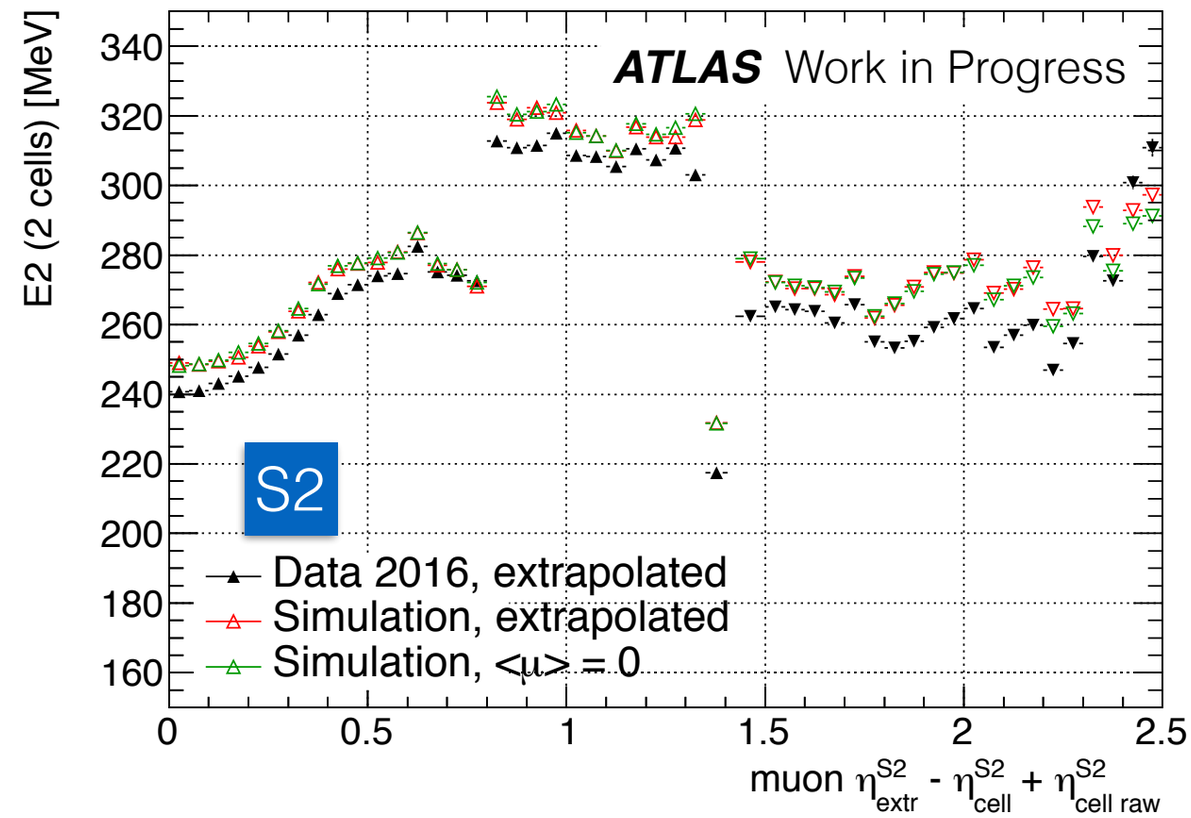



- Average pileup 30% lower in Run-1 (+other beam conditions), so pileup impact not that high.

# Change of noise model

# Closure with gaussian noise model




- Happy if **red** and **green** **match**!
- **S1**: **good agreement in the central part**, **still a large issue in the far regions**.
- **S2**: **good agreement everywhere**!
- Can we try to **find out why**?

# Noise modelling

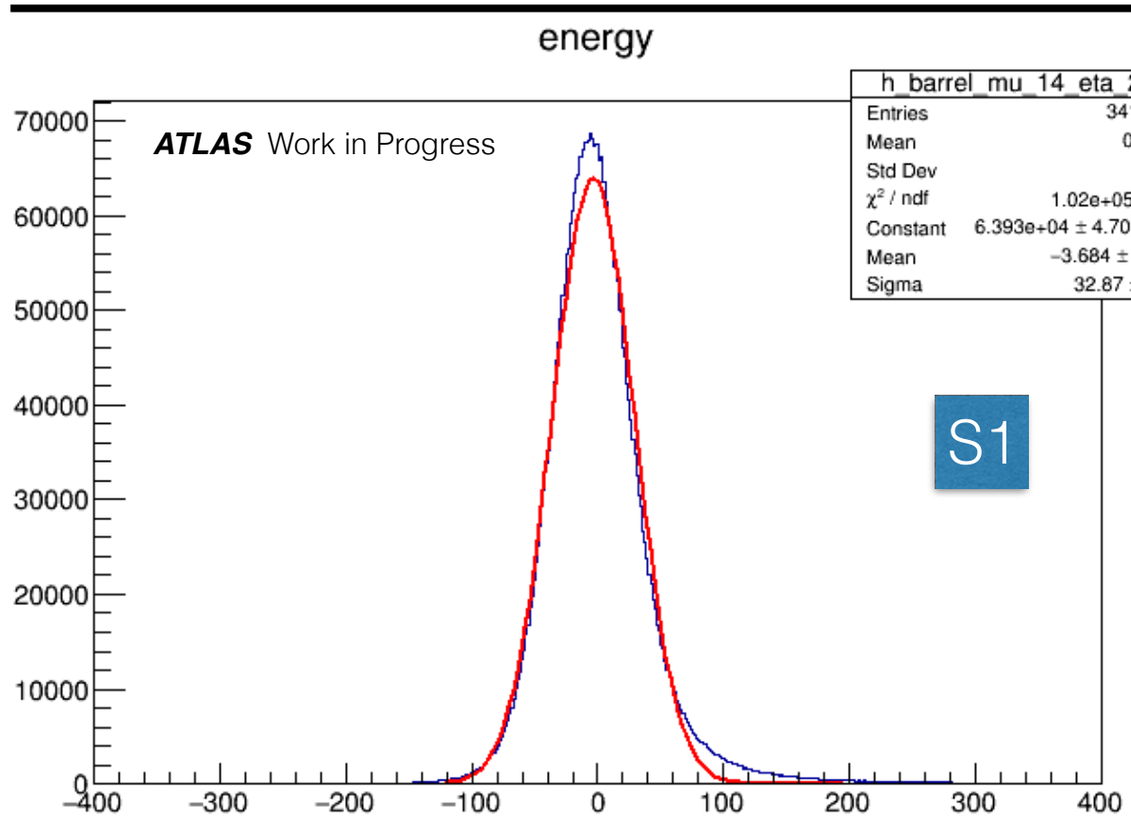
- **Noise assumed to be gaussian and centred at 0.**
- **Is it true?**

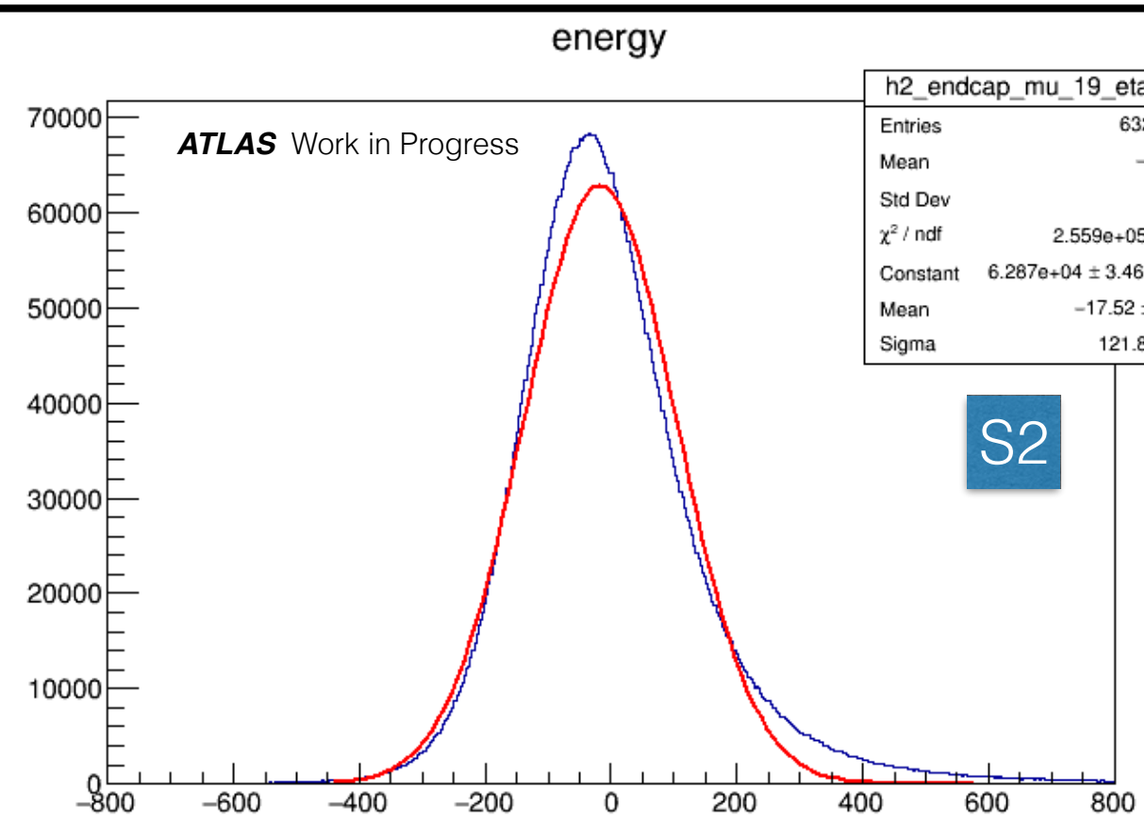
# Noise modelling

- **Noise assumed to be gaussian and centred at 0.**
- **Is it true?**

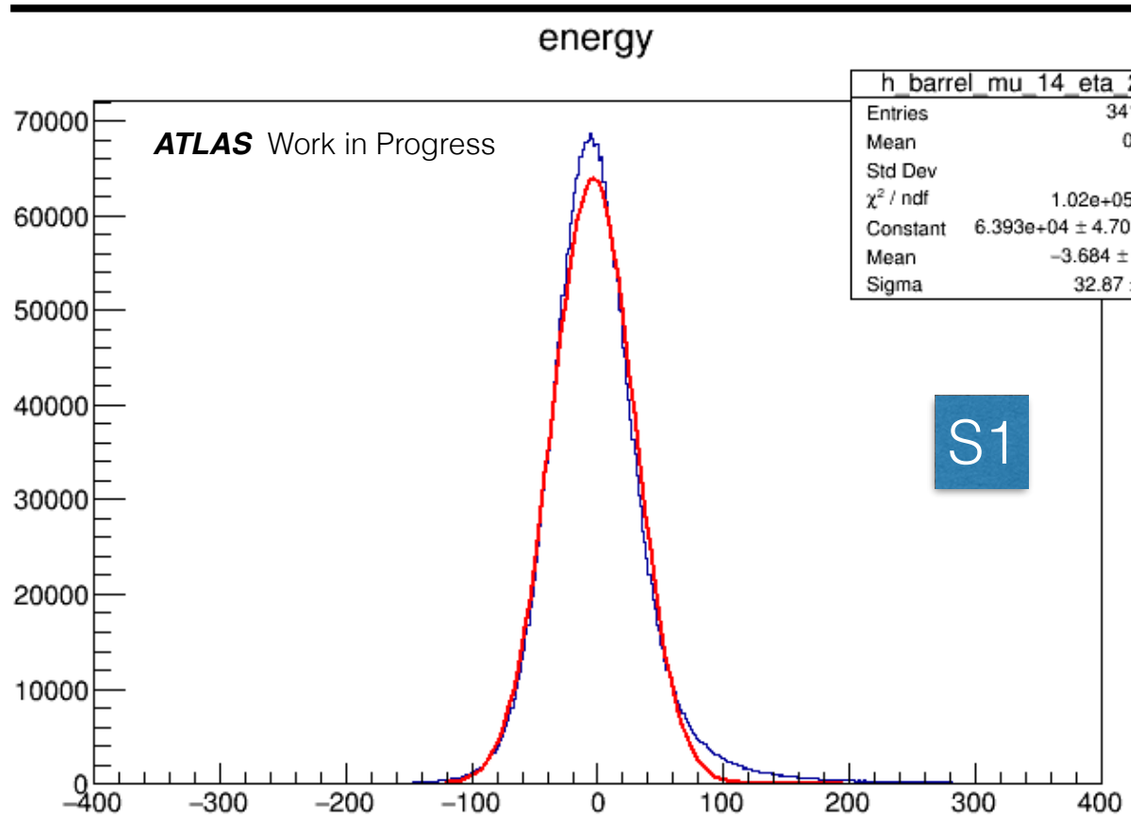
- **Generate noise "templates"** (= shapes):
  - from events with no hard-scatter collision at all (only pileup)
  - **contain only noise** (electronic and pileup).

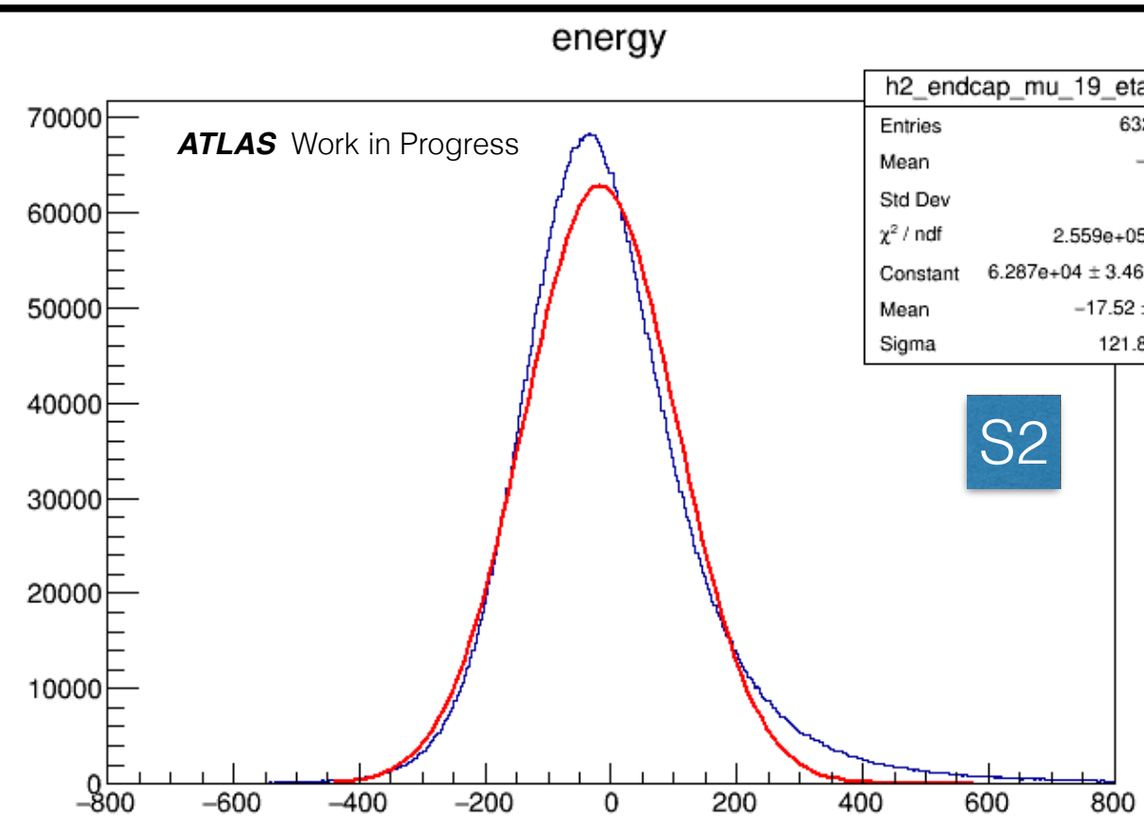
# Noise templates



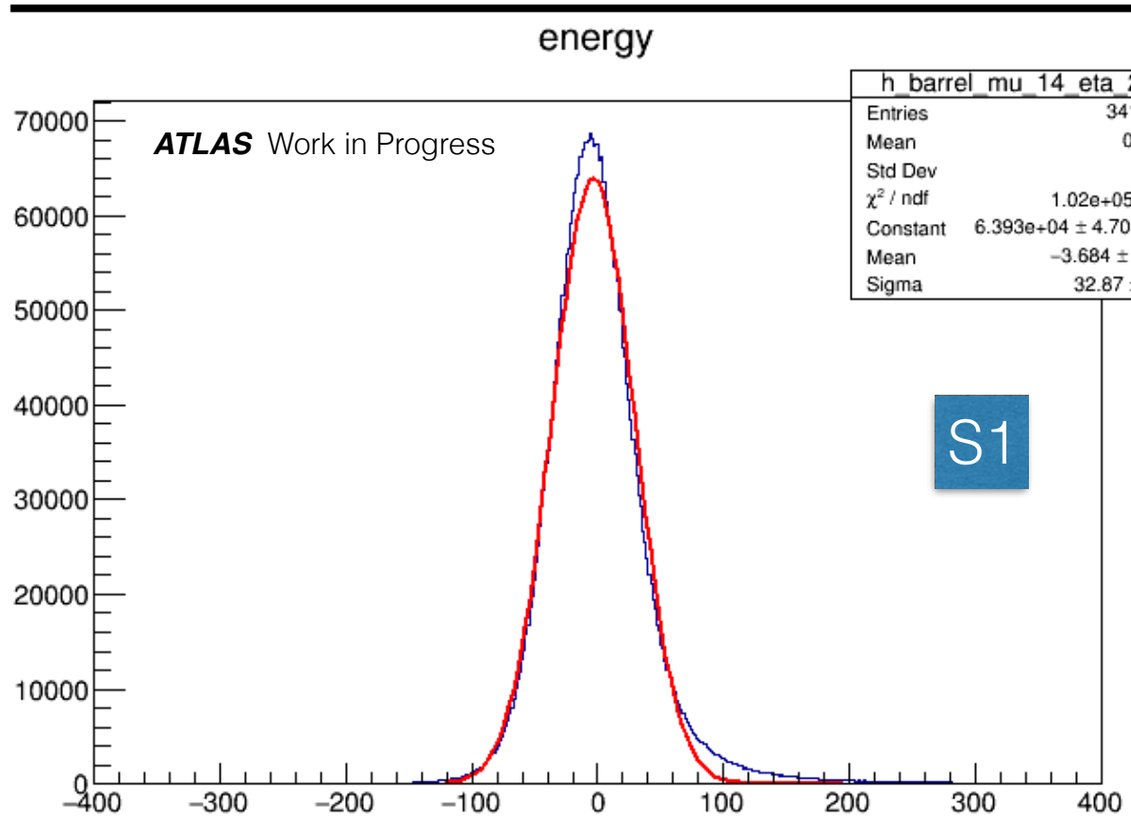
# Noise templates

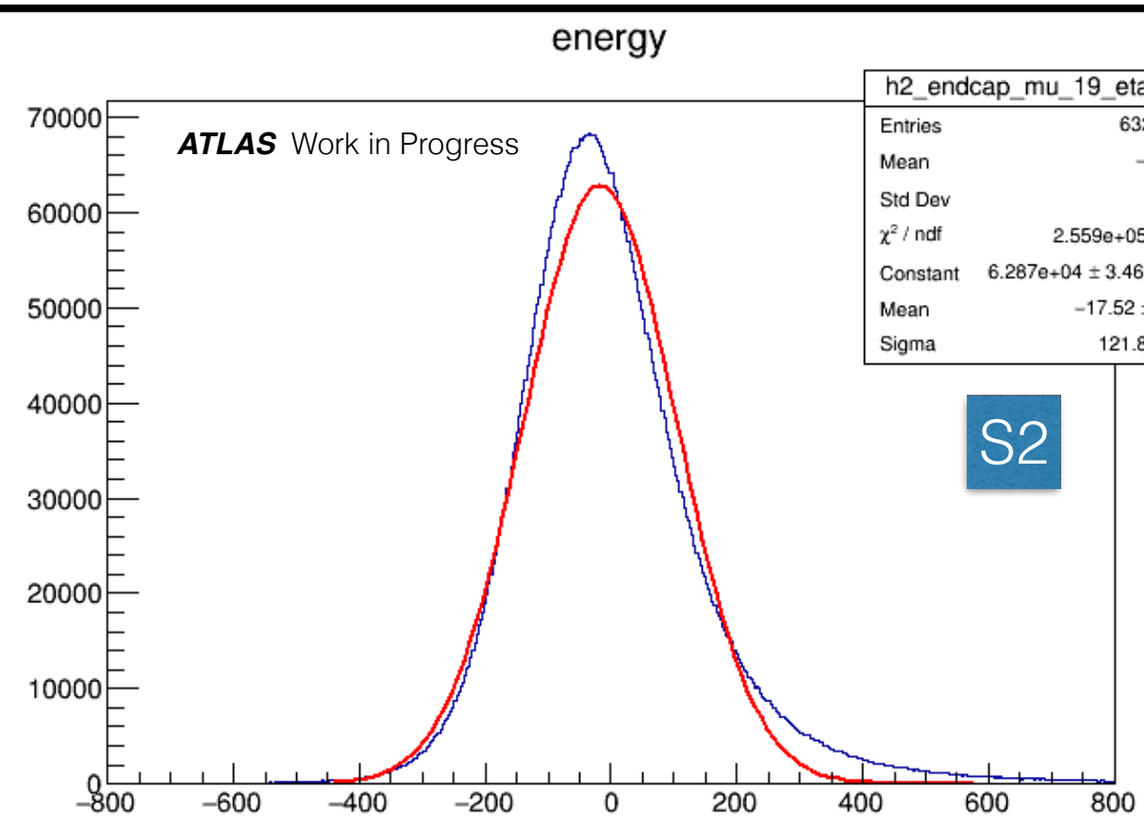



- The **noise is definitely not gaussian**.

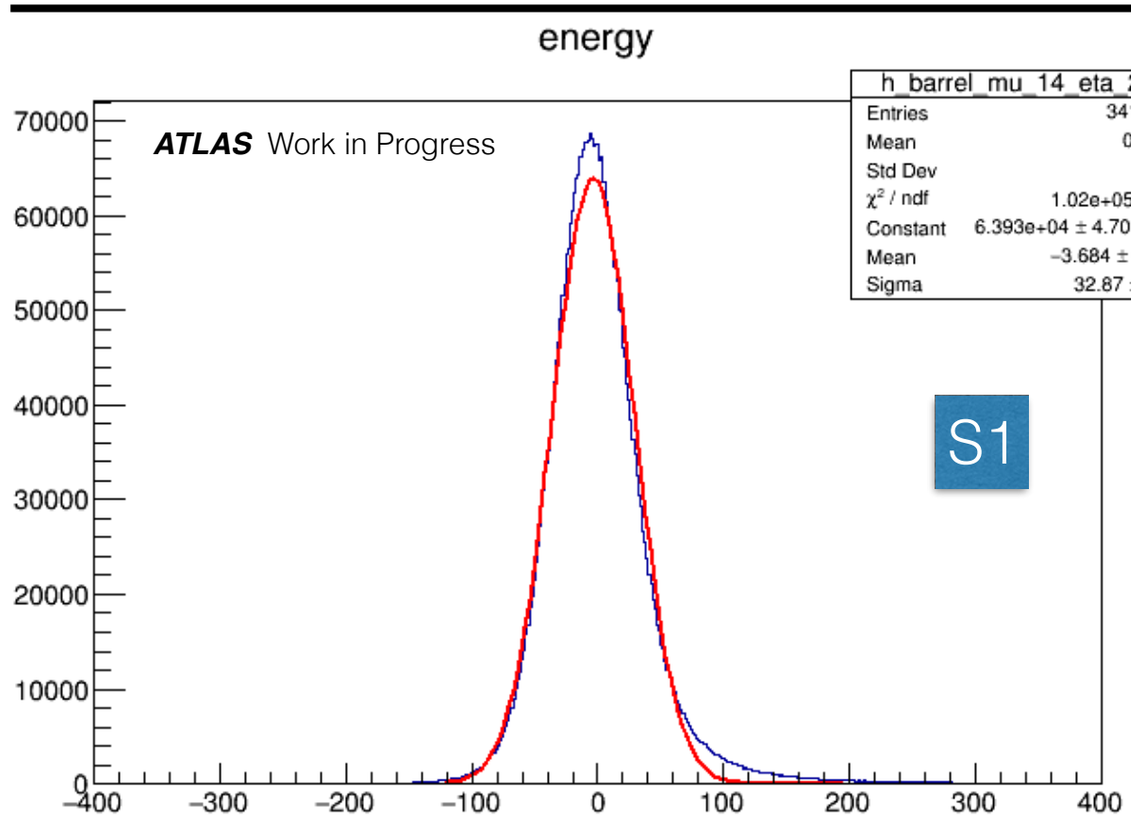
# Noise templates

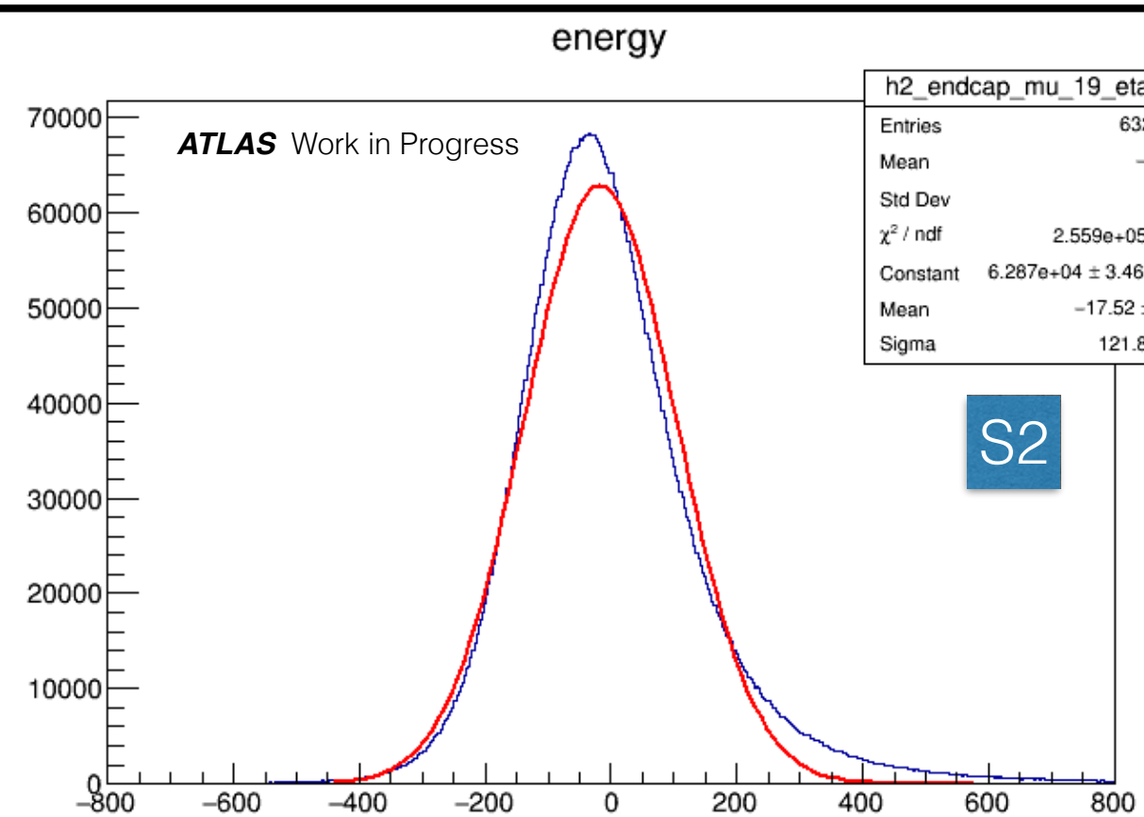



- The **noise is definitely not gaussian**.
- So **let's change the noise model**!

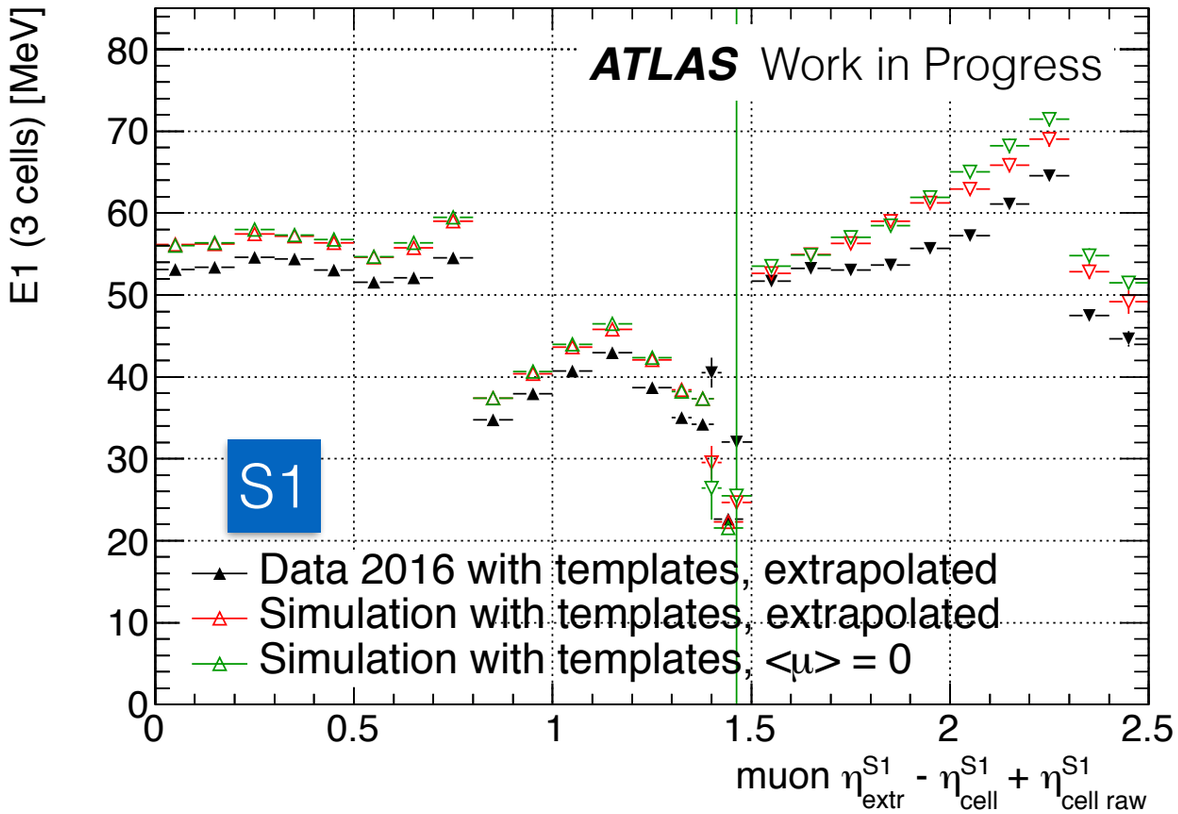
# Noise templates

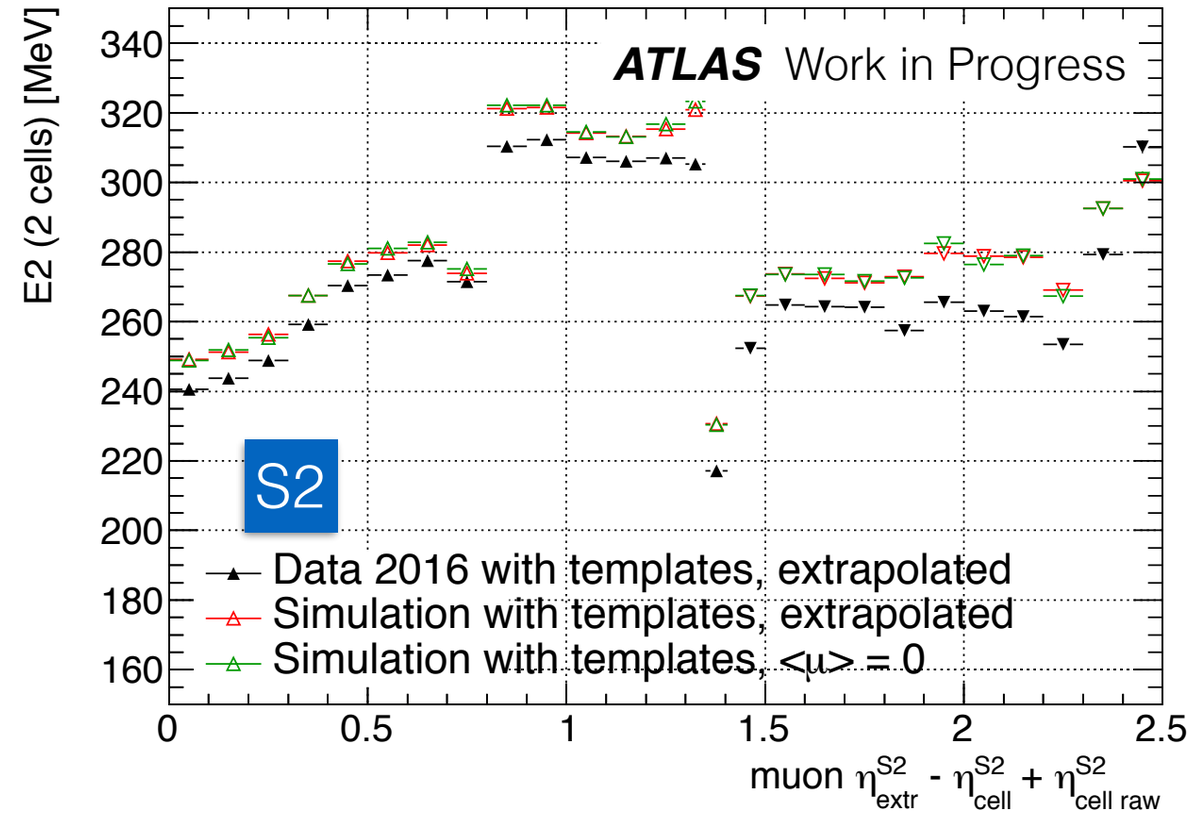



- The **noise is definitely not gaussian**.
- So **let's change the noise model**!
- Use **Landau⊗template** instead of **Landau⊗Gaussian**!

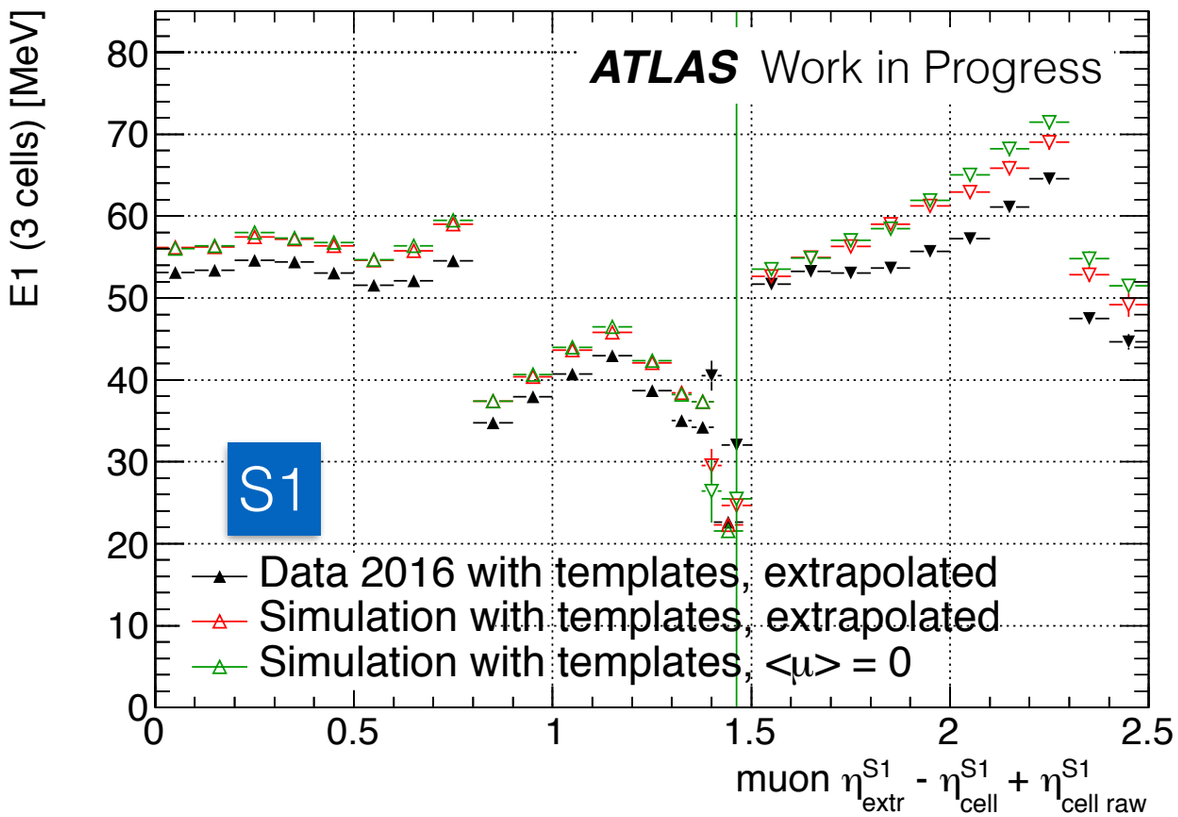
# New validation test with templates

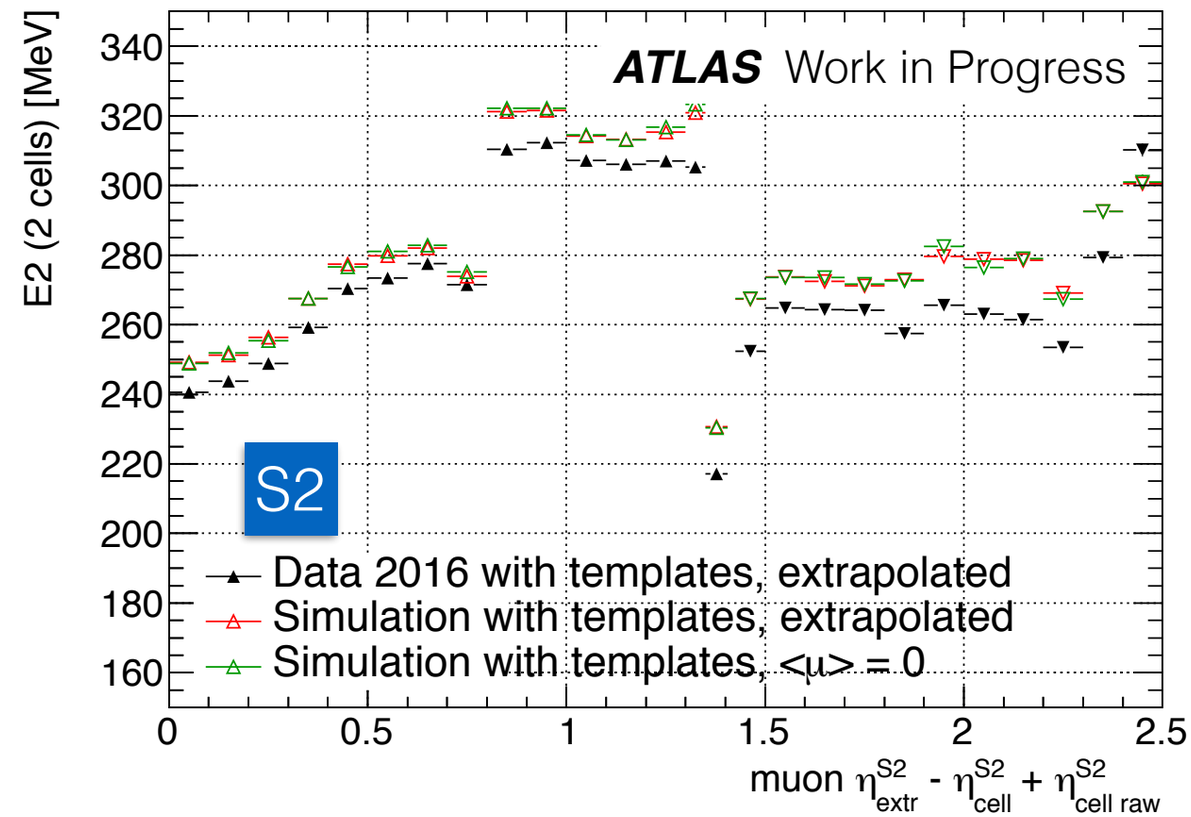



- Happy if **red** and **green** **match**.

# New validation test with templates

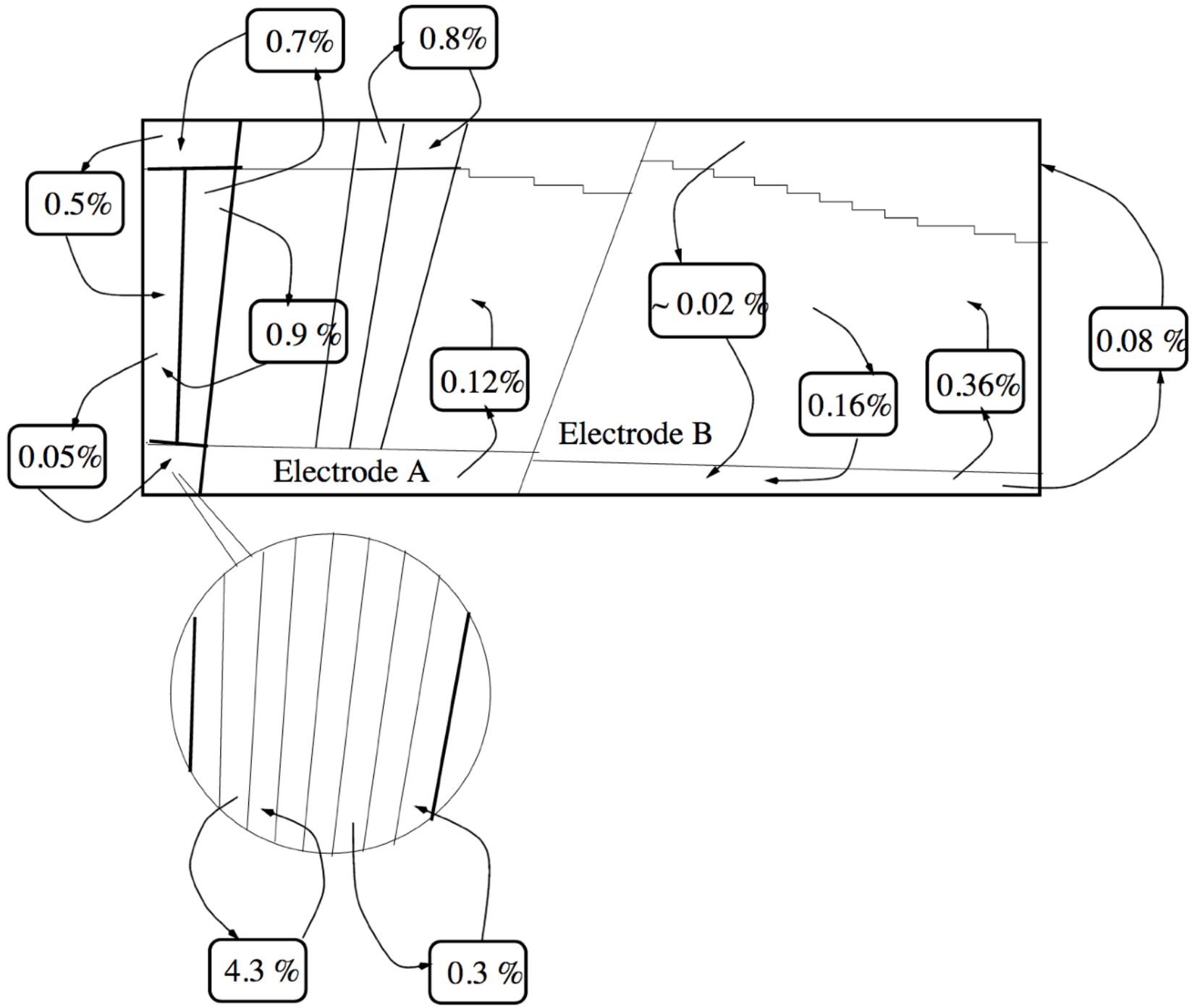



- Happy if **red** and **green** **match**.
- **Fair agreement**, difference taken as a systematic on the result.

# Number of cells used in energy computation

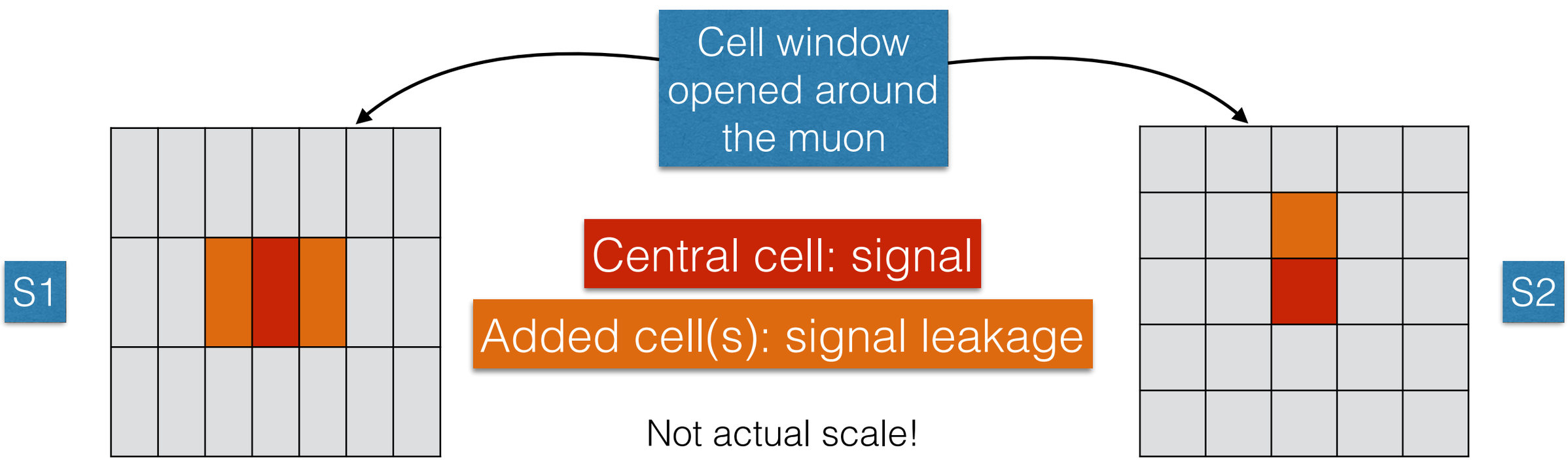
# Cross-talk in the barrel



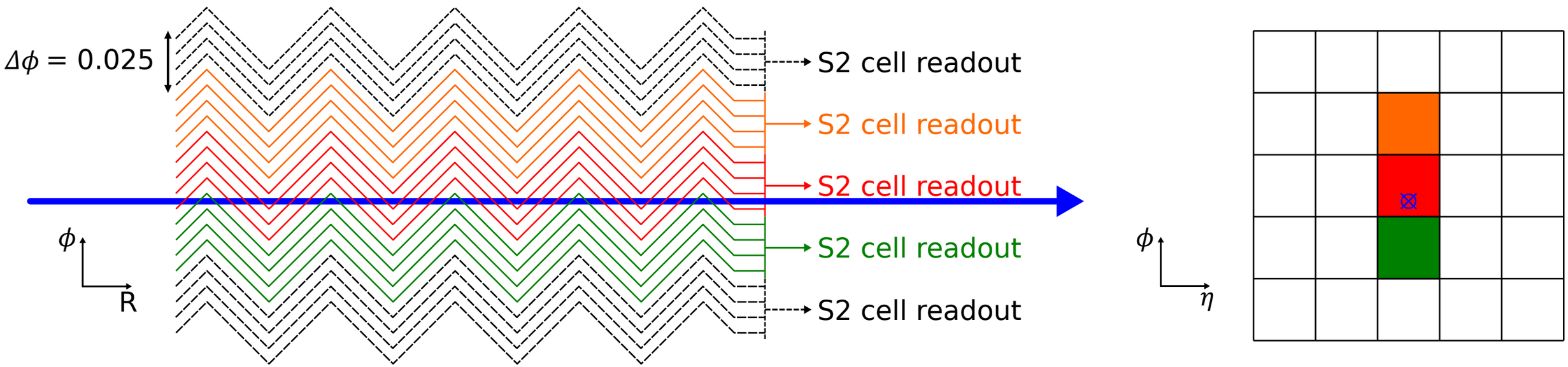
# E1/E2 intercalibration method

- To build the distribution, the energy deposit is actually summed over
  - **3 cells in <u>eta</u> for L1:** correct for the cross-talk (10-15%)
    - take central* + left + right
  - **2 cells in <u>phi</u> for L2:** correct for accordion geometry
    - central* + maximum energy cell between top or bottom

*: "central" means "cell closest to the track intersection in this layer"*



# Geometry argument for S2



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- http://cms-results.web.cern.ch/cms-results/public-results/publications/HIG-16-041/index.html
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- http://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/PERF-2013-05/