

# Verify the LPM effect

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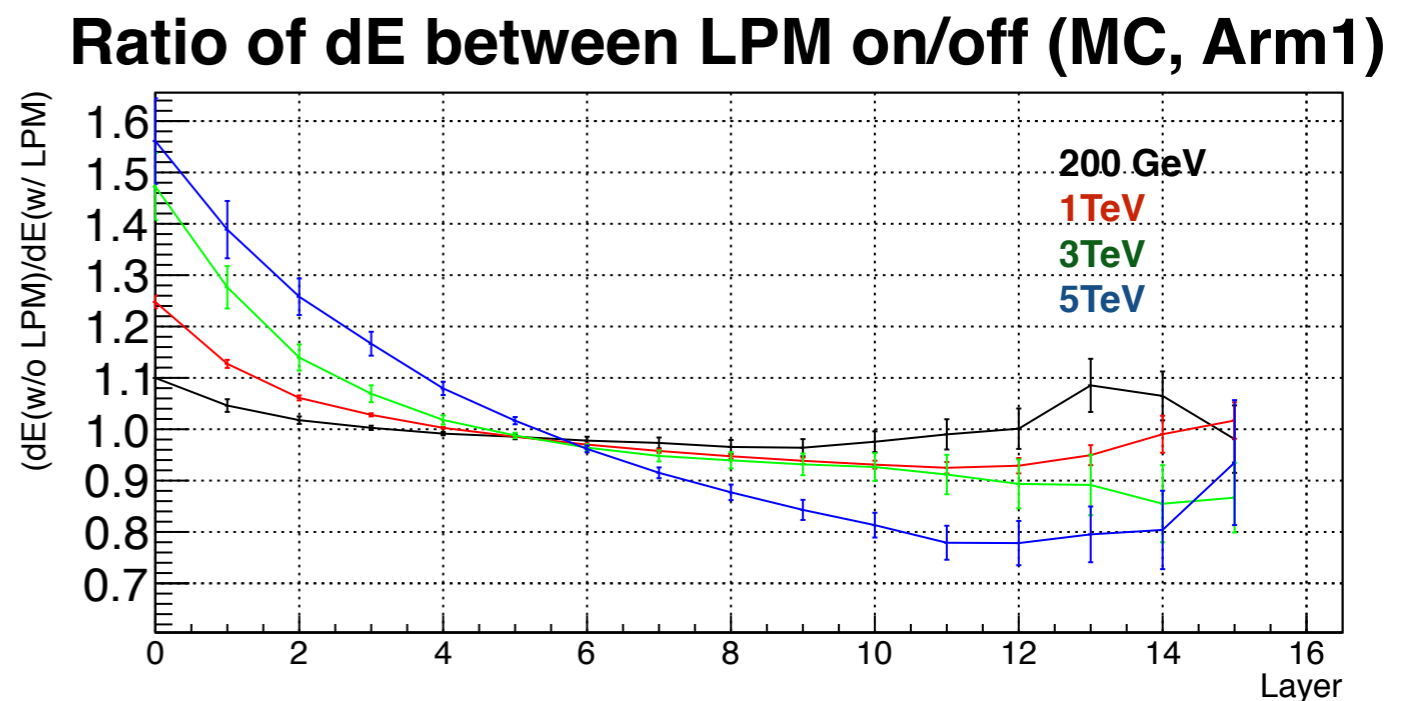
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# Motivation

**Verify the LPM effect by using 13 TeV Data (updated detectors.)**

1. Compare the transition curve of DATA and LPM ON/OFF MC by Chi-square test.  
-> Right figure shows the difference of energy deposit of each layer between LPM on/off MC.
2. Study the correction factors to LPM ON MC as agree with Data.



# Analysis flow

**In order to compare the transition curve of DATA and LPM ON/OFF MC by Chi-square test, I studied ...**

1. Study the uncertainty of DATA  
<- energy scale uncertainty of each layer and
2. Test the MC setup.  
As energy scale was adjusted by using MC data, DATA(LHC2015) transition curve (= dE) need to agree with MC transition curve at SPS energy region (200 GeV).

-> Not good agreement was occurred only Arm1 !  
It is clear that development of MC shower is delayed. (ref. P)  
However Makino's study confirmed good agreement between MC (SPS-setup) and DATA(SPS2015).  
-> Tune the TAN thickness

**Problem 1**

3. Because MC-data-set was generated from mono-energy photon, the multi-hits and the hadron contamination need to study carefully.  
<-These are need to take in into account as uncertainty.

-> Compare the Full MC (LPM ON) and mono-energy MC  
-> Large disagreement at high energy region (3 TeV~).  
-> Hadron contamination was large (~40%@4TeV), new PID method was added.

**Problem 2**

# Data Set

**Arm1**

**Arm2**

**Data (2015LHC)**

RUN44299 - RUN 45106 (Fill)

<- special trigger events were rejected

8.4M events

9.9M events

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**Full - MC  
(generated from p-p collision)**

$10^8$  events (QGSJET2-4, LPM ON)

$5 \times 10^7$  events (EPOS LHC, LPM ON)

There are no LPM-OFF full MC data-set...

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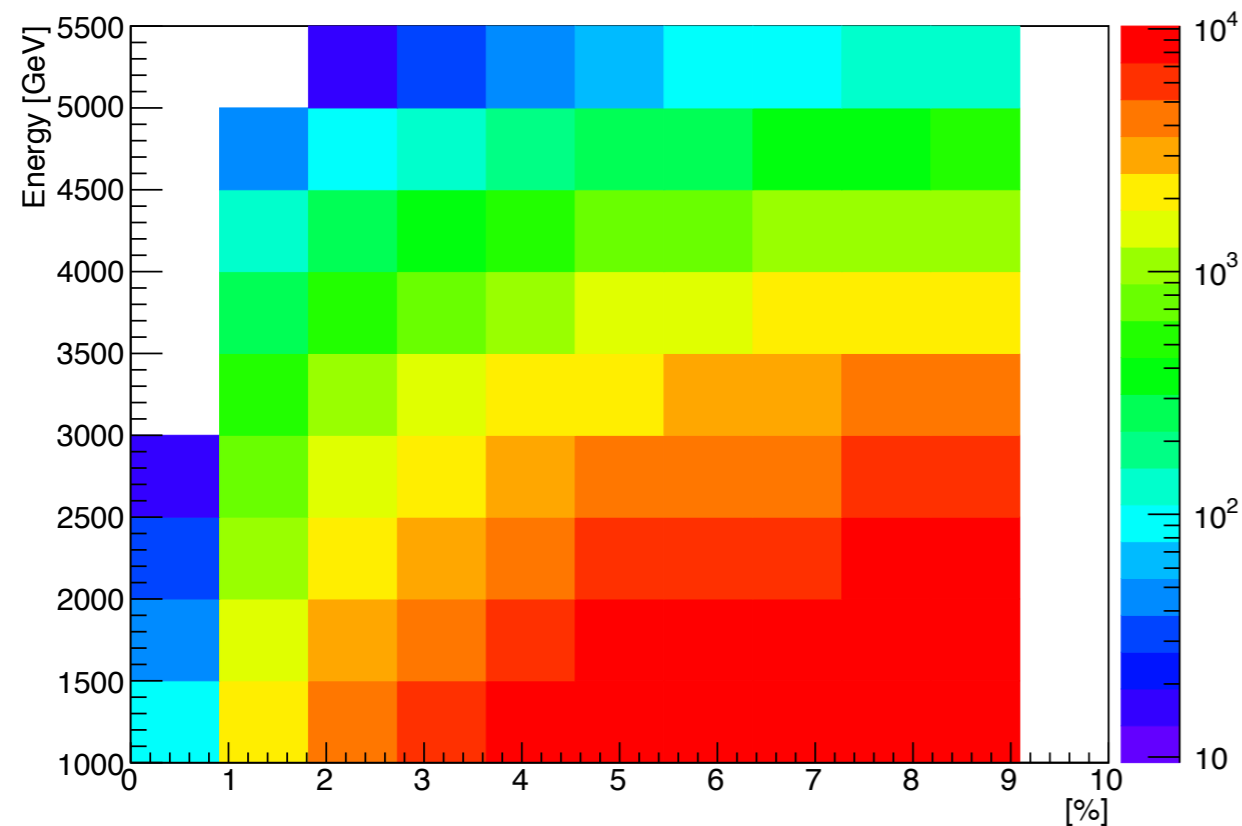
**mono - MC  
(Instead photon  
with mono-energy  
@ TS center)**

200, 500, 1000, 2000, 3000, 3500, 4000, 4500 GeV  
~1000 events (LPMON/OFF)

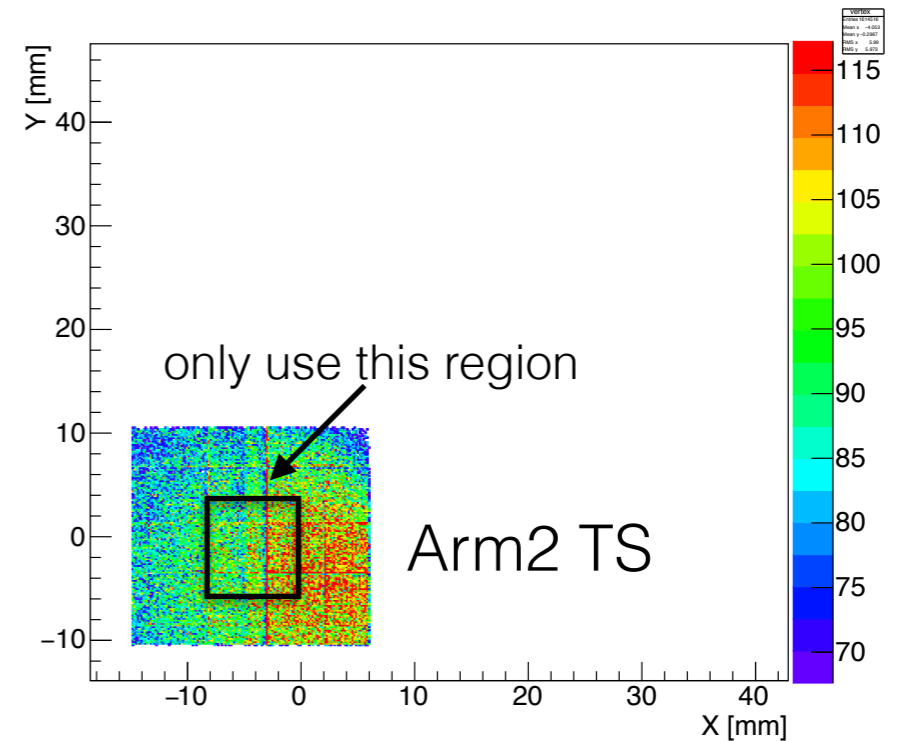
# EventSelection

- Multi-hit cut
- PID cut
- edge cut : 8.5 mm  
3 mmx3 mm (Arm1)  
8 mm x 8mm (Arm2)
- energy cut  
 $E \times \pm 3 \% \leftarrow 3\%$  was decided from statistical of Data

Statistical Test



vertex

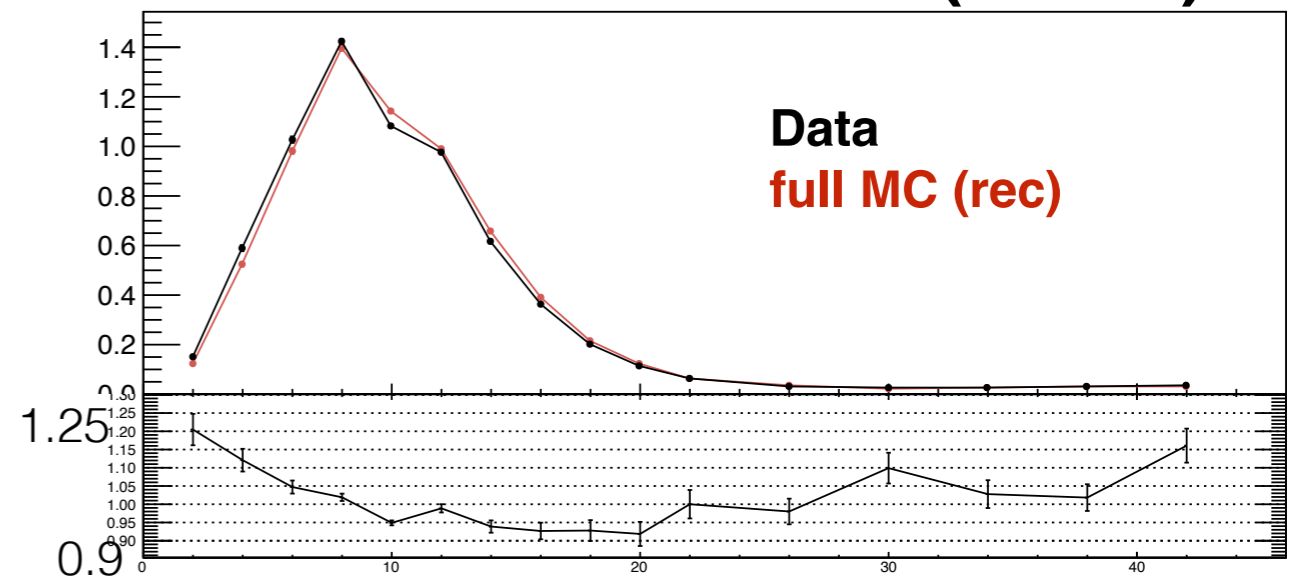


**In order to statistical error make smaller than 1%  
100 events are needed .**

# ① Problem 1

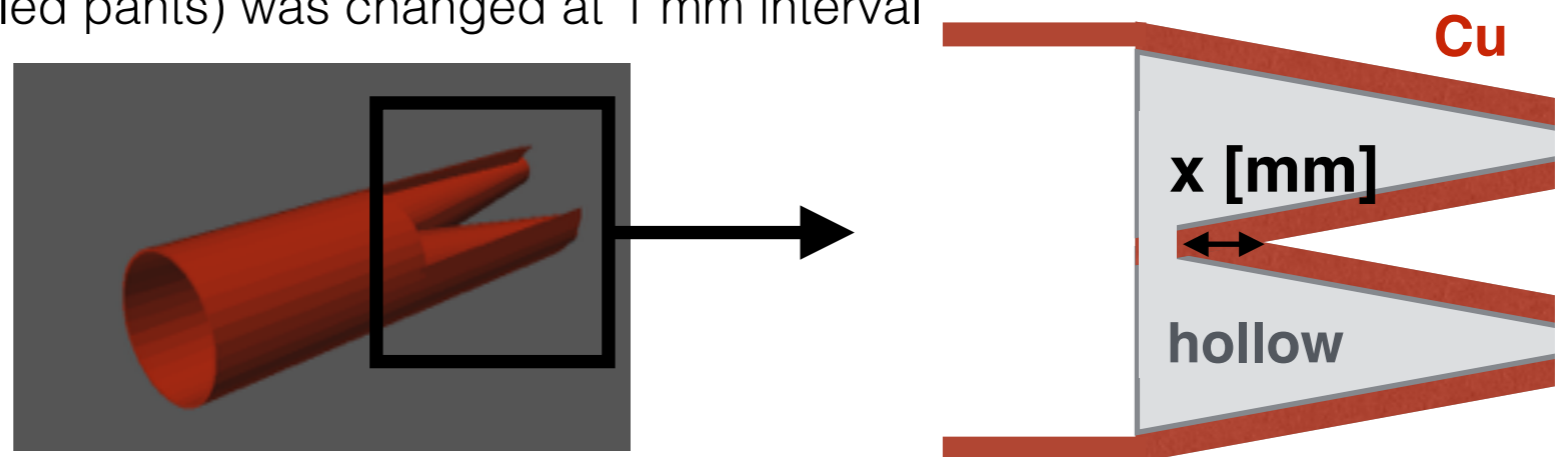
Disagreement between Data and MC at 200 GeV  
 -> It is clear transition curve of MC was derailed compared with data.

## Transition curve (Arm1)



Disagreement between Data and MC at 200 GeV  
 -> It is clear transition curve of MC was derailed compared with data.  
 =>The End2End pipe thickness (called pants) was changed at 1 mm interval  
 Default TAN thickness : 12 mm

change x [mm]

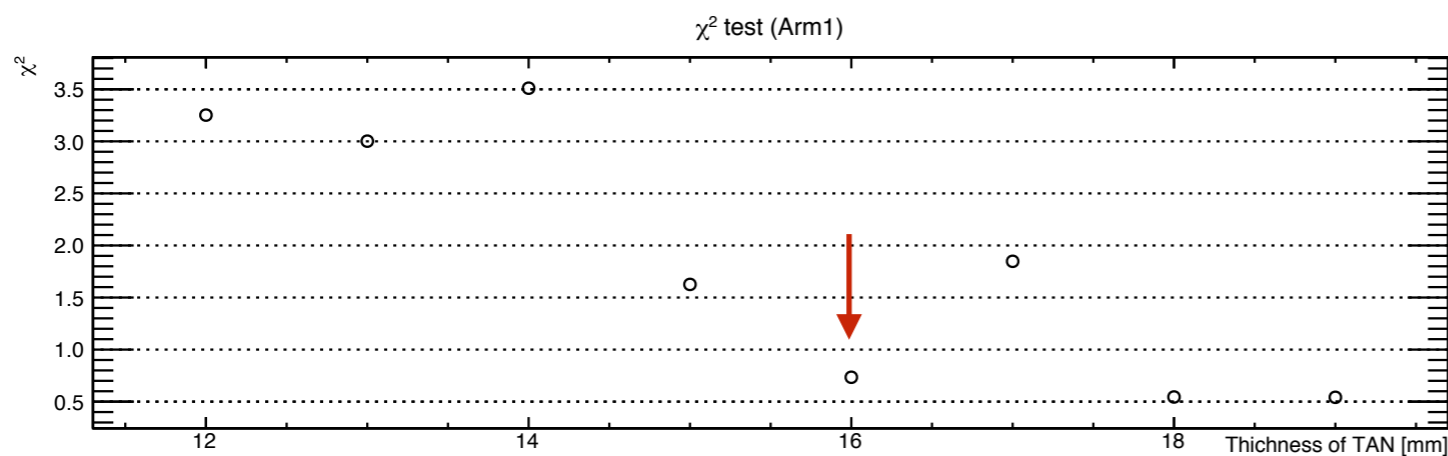
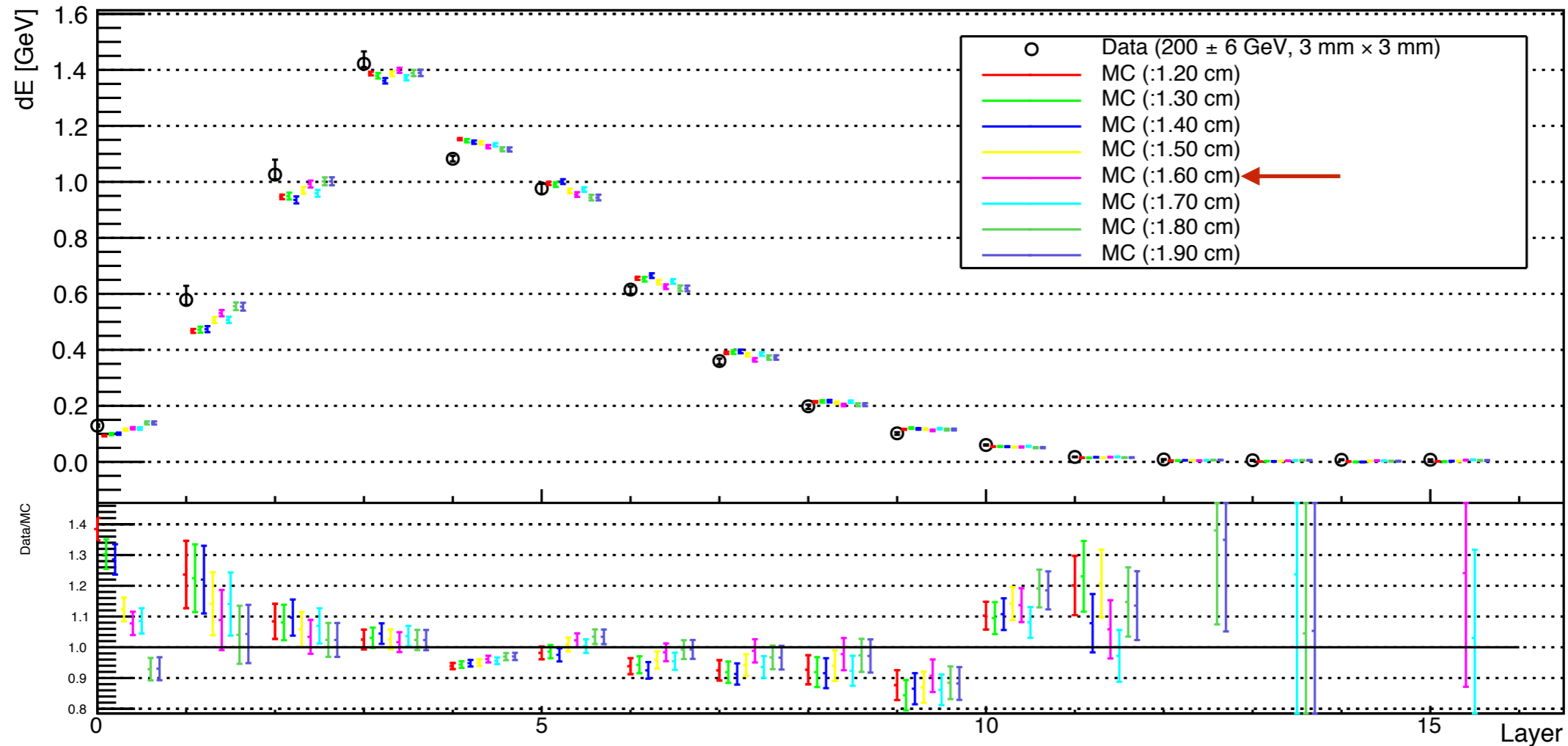


\*This value was modified by Mitsuka-san and former value was 18 mm (plan design value)

[http://lhcf1.stelab.nagoya-u.ac.jp/PukiWiki/?plugin=attach&refer=Weekly%20LHCf%20Meeting&openfile=LHCfAnalysisMeeting\\_140916\\_mitsuka\\_MC.pdf](http://lhcf1.stelab.nagoya-u.ac.jp/PukiWiki/?plugin=attach&refer=Weekly%20LHCf%20Meeting&openfile=LHCfAnalysisMeeting_140916_mitsuka_MC.pdf)

# Transition Curve of each TAN thickness

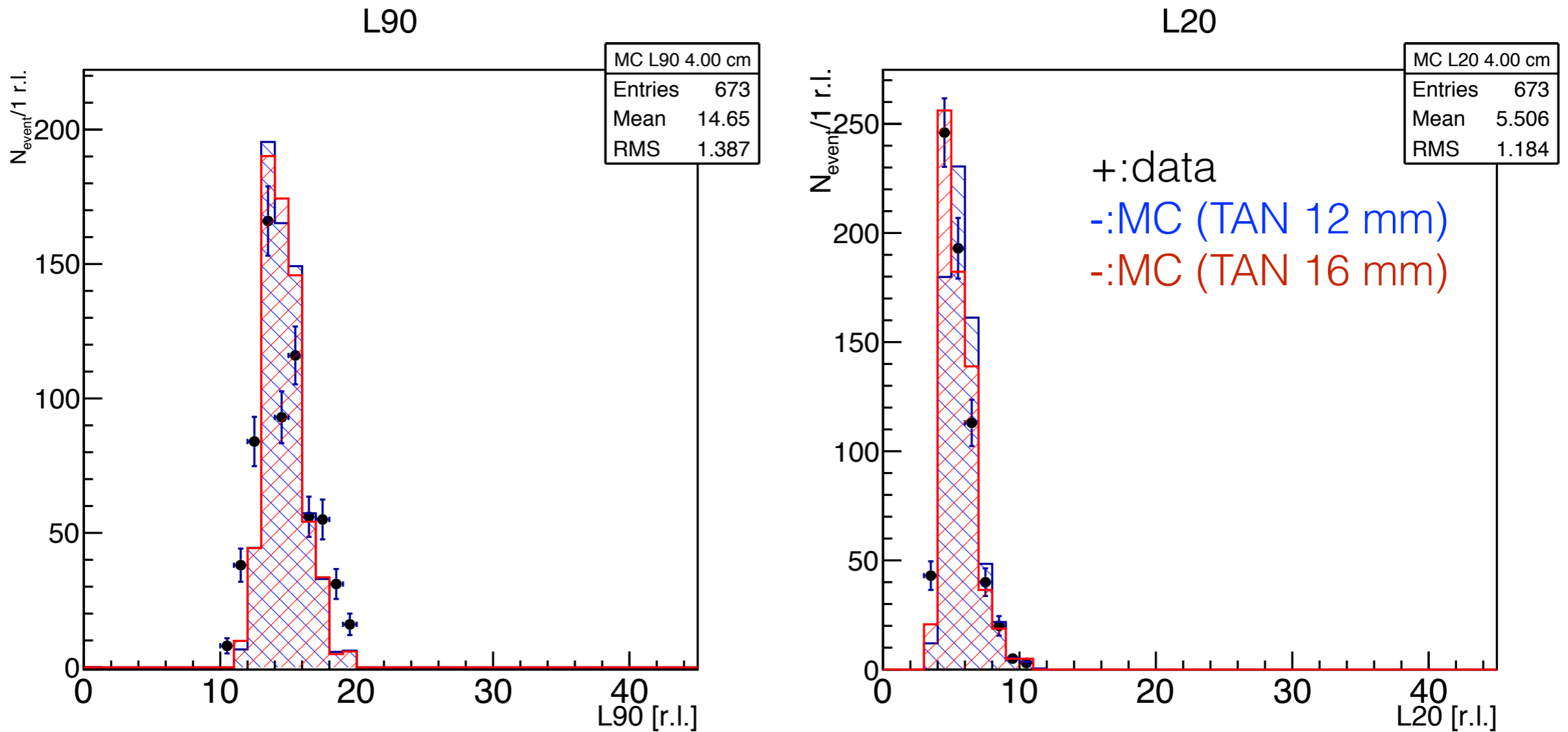
Transition curve (Arm1, 200GeV)



**In case of 16 mm,  
the most good agreement with data**



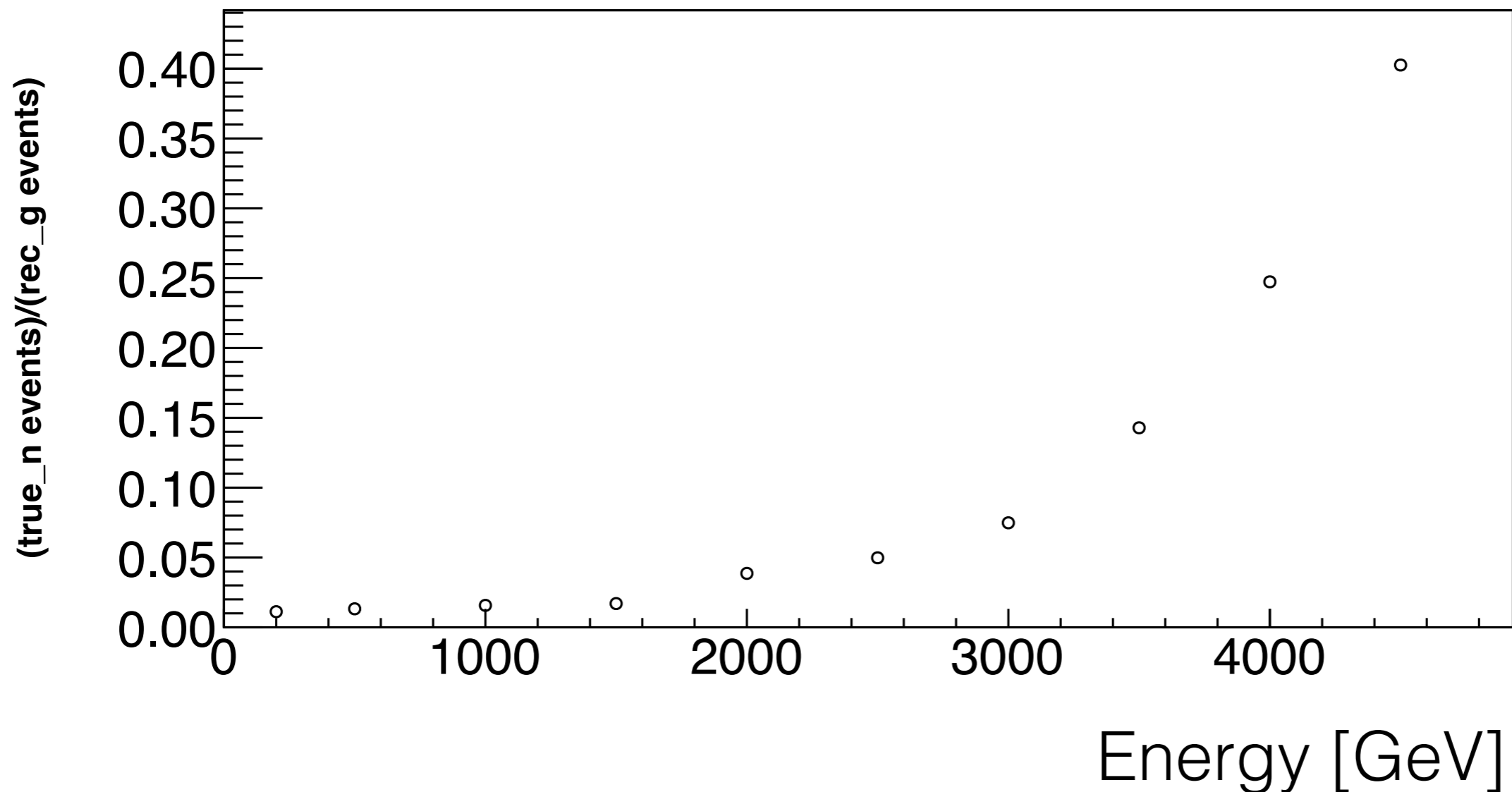
# L90 & L20 (Arm1)



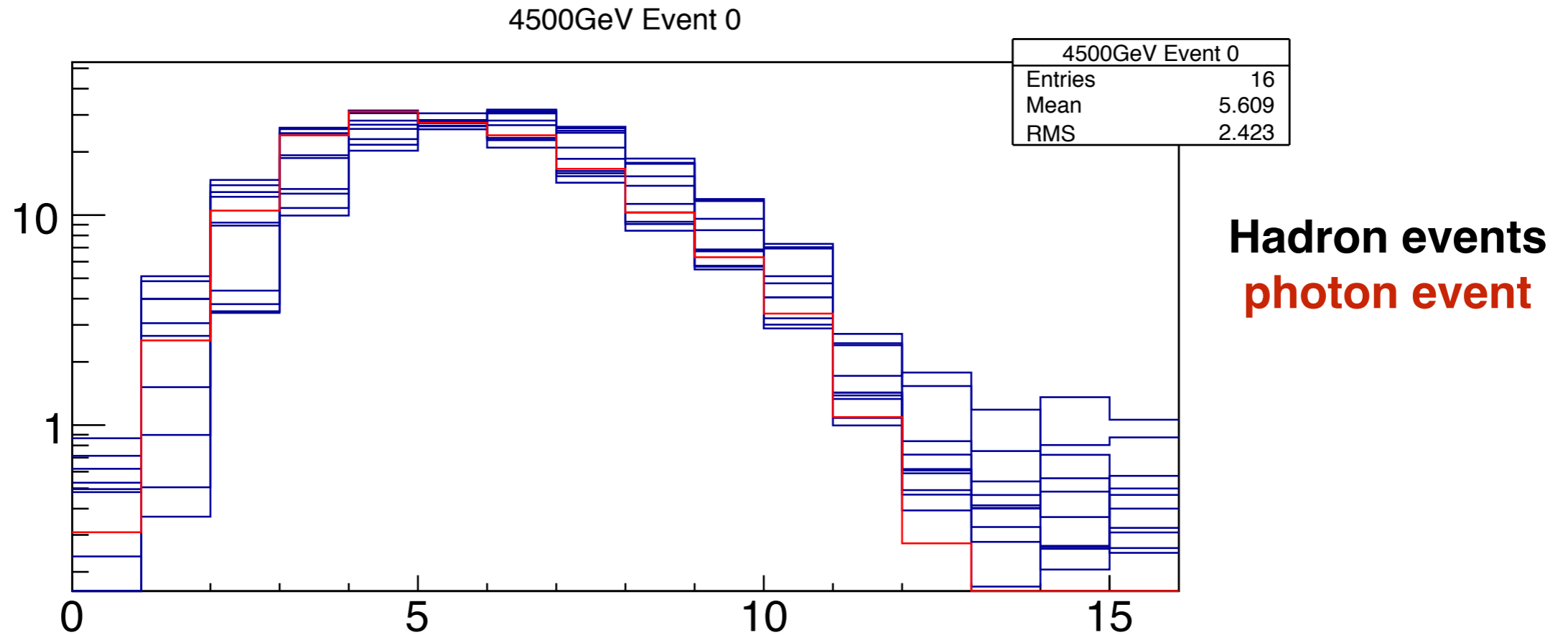
**L90 :There are not big difference between default value (12 mm) and 16 mm in**  
**L20 : In case of 16 mm more good agreement with data**

# Problem 2 . PID

Compare the Full MC (LPM ON) and mono-energy MC (LPM ON) => Not good agreement  
There are many hadron contamination more than 3 TeV  
<= even after L90 cut, ~40 % hadron contamination (studied by Full MC, QGSJET2-4)



# Additional PID selection



Because hadron shower continue deep layer (13-15 layers)  
We can identify the neutron event by summation of last 3 layers.

# Summary

- Verify the LPM effect by using LHC2015 Data set
- In case of Arm1 MC, TAN thickness was changed to 16 mm from 12 mm as agree the Data.
- For test of LPM, hadron contamination was not negligible at high energy region ( $\sim 40\%$  @4 TeV ). Therefor by using summation of last 3 layer energy deposit, new PID-cut was adopted.

# dE distribution (Arm1, 200 GeV)

+:data

-:MC (TAN 12 mm)

-:MC (TAN 16 mm)

