LPM effect analysis

Y.Itow for Eri Matsubayashi

LHCf/RHICf meeting at Florence

26 Nov, 2018

Landau-Pomeranchuk-Migdal (LPM) Effect

- For very high energy photons($>10^{13}$ eV), Bremsstrahlung, pair production, suppressed in a dense matter
- Radiation lengths get smaller, then EM shower development gets slower in LHCf detector as a function of $E\gamma$.

PHYSICAL REVIEW VOLUME 103, NUMBER 6 SEPTEMBER 15, 1956

Bremsstrahlung and Pair Production in Condensed Media at High Energies

A. B. MIGDAL
Academy of Sciences of U.S.S.R., Moscow, U.S.S.R.

(Received May 11, 1956)

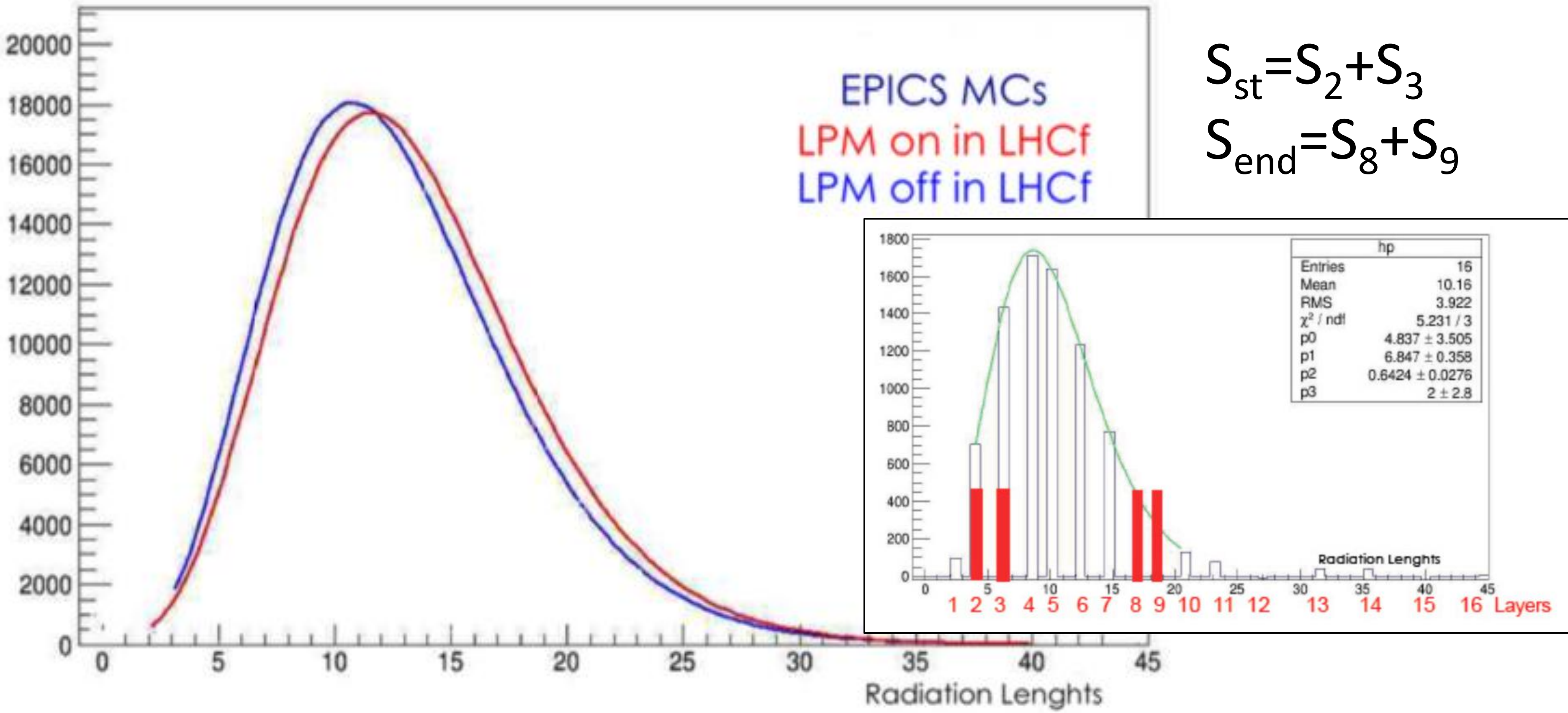
The effect of multiple scattering on bremsstrahlung and pair production is considered. The probability of these processes decreases considerably at energies $\gtrsim 10^{13}$ ev.

The calculations are carried out with the aid of the density matrix. The formulas thus obtained yield the probability of pair production and bremsstrahlung for arbitrary electron and photon energies.

LPM study in LHCf

- M.Del Prete studied on LHCf ARM2 for 7TeV p-p and 5 TeV p-Pb data in 2016
  - EPJ Web of Conferences **126**, 05003 (2016)
  - Use shower start/end point, comparing MC w/ or w/o LPM
  - Results support LPM on, but not entire picture consistently understood. Need check detector systematics.
- Eri Matsubayashi takes over the analysis with new method for her PhD work in 2016
  - After she left to industry in 2017, efforts still going on slowly but steadily (1~2 TV meetings/month) with Itow

LPM effect on LHCf shower curve

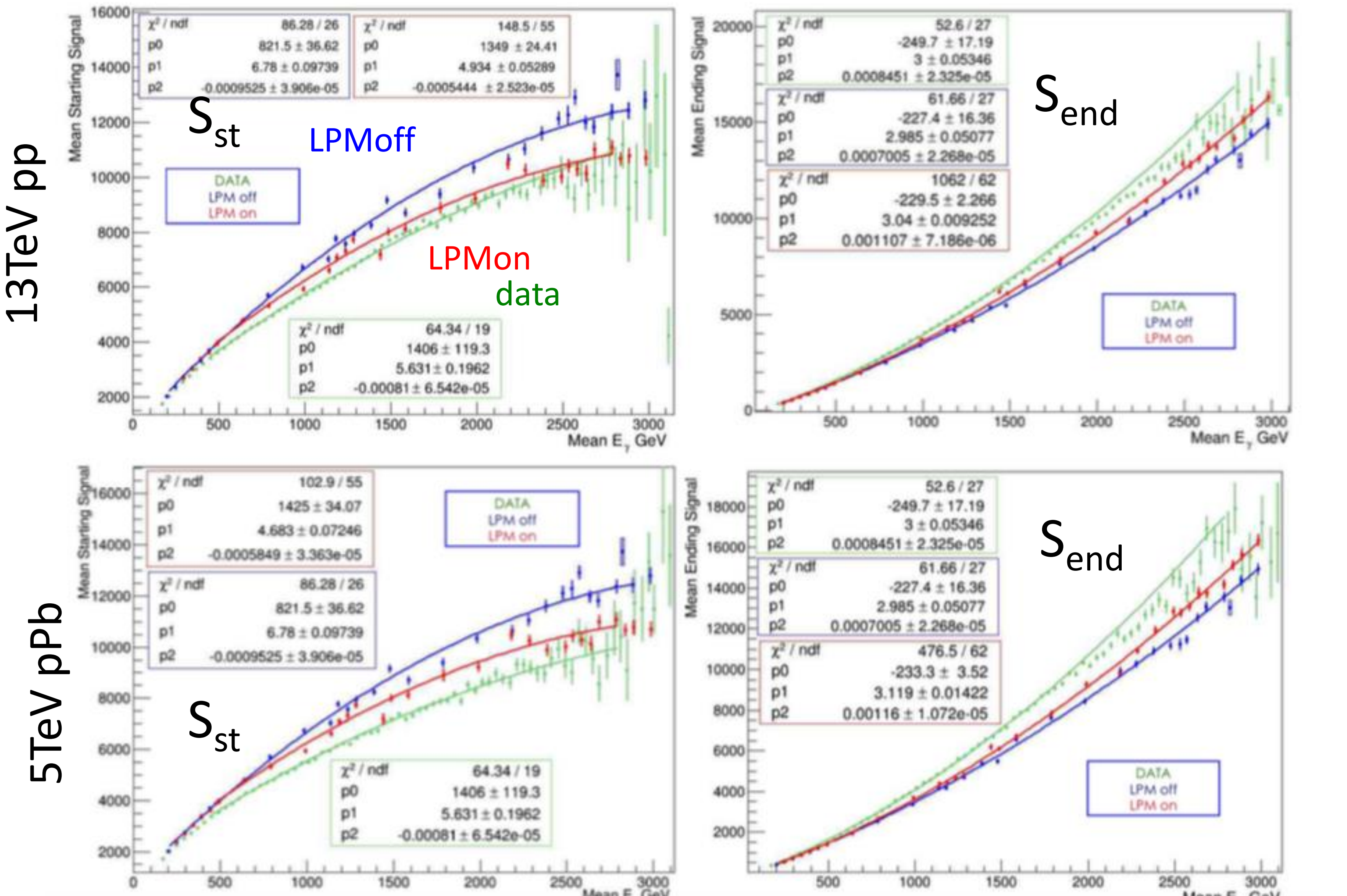


$S_{st}=S_2+S_3$

$S_{end}=S_8+S_9$

M.Del Prete, EPJ WoC **126**, 05003 (2016)

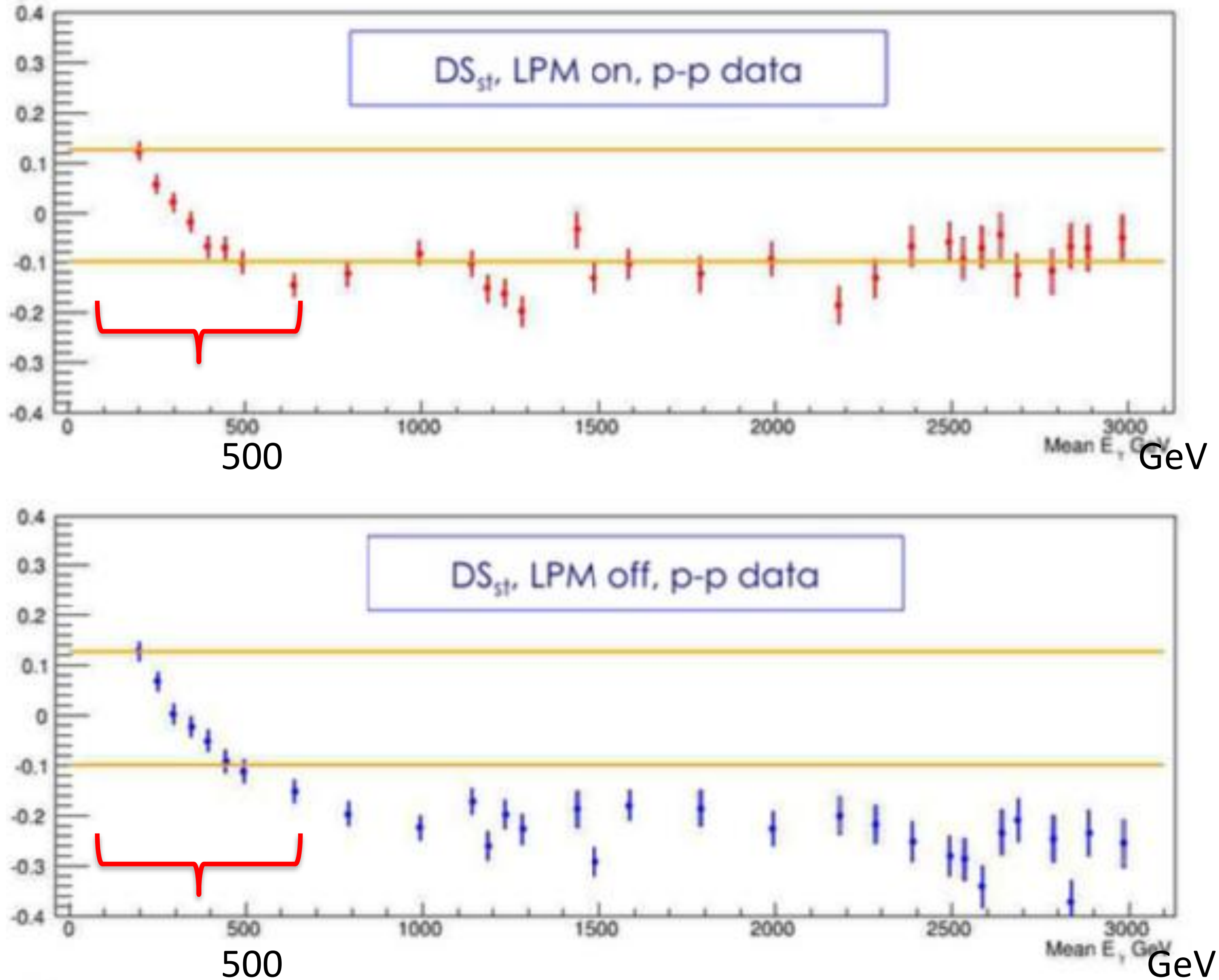
Shower start/end vs Eγ



M.Del Prete, EPJ WoC **126**, 05003 (2016)

Control region (Eγ<600GeV) should agree

$$DS_{st}\% = \frac{S_{st}^{data} - S_{st}^{MC}}{S_{st}^{data}}$$



M.Del Prete, EPJ WoC **126**, 05003 (2016)

Matsubayashi's new analysis

- Eri Matsubayashi takes over the analysis with new method for her PhD work in 2016
  - After she left to industry in 2017, efforts still going on slowly but steadly (1~2 TV meeting/month) with Itow
  - Use entire shower curve from LHCf ARM2-TS 13 TeV pp
  - Revisit detector systematics and retune MC @E<500GeV
  - See her LHCf wiki "matsubayashi info"

Attach file: 20181114_matsubayashi.pdf 7 download [Information] 201801031_Matsubayashi.pdf 5 download [Information] 201801001_Matsubayashi.pdf 7 download [Information] 20180821_Matsubayashi.pdf 5 download [Information] Matsubayashi_20180806.pdf 8 download [Information] 20180704_matsubayashi.pdf 6 download [Information] 20180627_matsubayashi.pdf 26 download [Information] 20180606_Matsubayashi.pdf 7 download [Information] 20180530_matsubayashi.pdf 16 download [Information] 20180510_MTBYS.pdf 8 download [Information] 20180419_matsubayashi.pdf 16 download [Information] 20180406_matsubayashi.pdf 14 download [Information] 20180330_matsubayashi.pdf 19 download [Information] 20180319_MTBYS.pdf 5 download [Information] matsubayashi_20180131.pdf 23 download [Information] 20180124_Matsubayashi.pdf 14 download [Information] 20180111_Matsubayashi.pdf 8 download [Information] MTBYS20171228.pdf 9 download [Information] 20171221_matsubayashi.pdf 19 download [Information] LPMtest.tar.gz [Information] 20171128.pdf 11 download [Information] todo.pdf 9 download [Information] MTBYS_20170810.pdf 23 download [Information] minuit_test3.cpp 2 download [Information] 20170621_LPM.pdf 25 download [Information] lpm_20160608.pdf 20 download

Matsubayashi's analysis strategy

$$\chi^2 = \sum_{i=1}^{10} \left(\frac{\alpha \times D(x_i) - T(x_i')}{\Delta D(x_i)} \right)^2 + \left(\frac{\alpha}{\Delta\alpha} \right)^2 + \left(\frac{\beta}{\Delta\beta} \right)^2 + \left(\frac{\gamma}{\Delta\gamma} \right)^2$$

- i : Layer (1-10)
- x_i : radiation length of each layer
- $x_{i'}$: modified radiation length of each layer
- $D(x_i)$: Measured dE
- $T(x_i')$: MC dE
- $\Delta D(x_i)$: Uncertainty of dE
- α : normalize factor for Energy uncertainty

$$x_i' = \gamma x_i + \beta$$

β : r.l. shift of beam pipe
γ : r.l. shift of tungsten

Tune MC and α,β,γ @E<200GeV
Verify MC @ E=500 GeV
Fit LPM E>500 GeV MC vs MC
Fit full 13 TeV

$$\Delta D(x_i)^2 = (\Delta D(x_i)^{stat})^2 + (a \times \boxed{\Delta D(x_i)^{sys}})^2$$

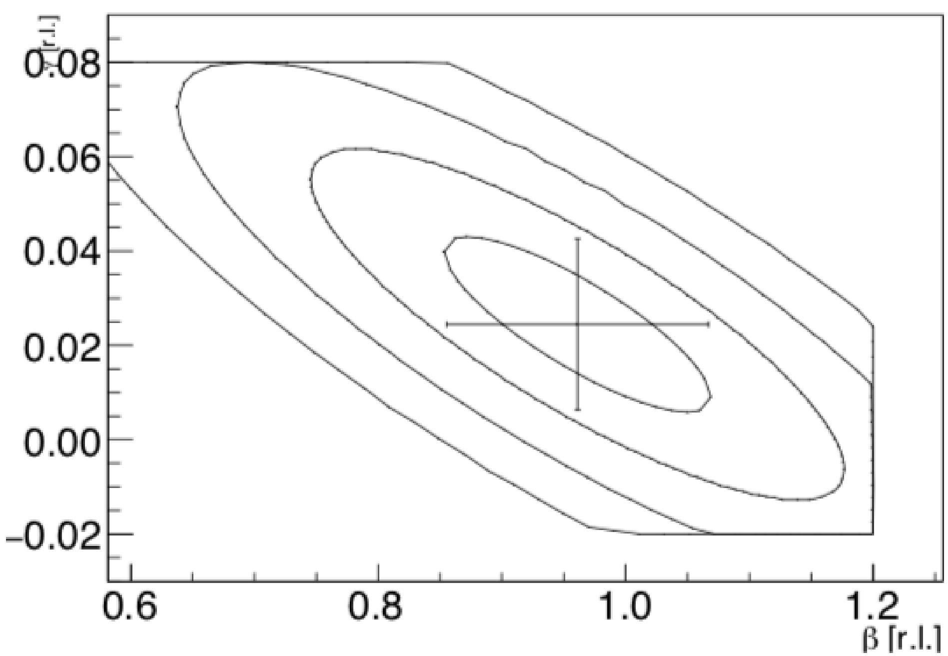
MC preparation

- Generate dedicated single-γ MC w/ and w/o LPM for template
- Mimic MC $E\gamma$ distribution to avoid strong E-slope in a energy bin
- Check wider 8x8mm area and position dependence of light collection considered
  - Non-uniformity systematic error
- Multi-hit systematics considered by comparing full End2End MC

MC retuning, systematic errors

- TAN thickness ?
- Accurate W-layer X_0 ?
- SPS gain parameter ?

Verified by control region
(E<500 GeV)



200 GeVだけで調整

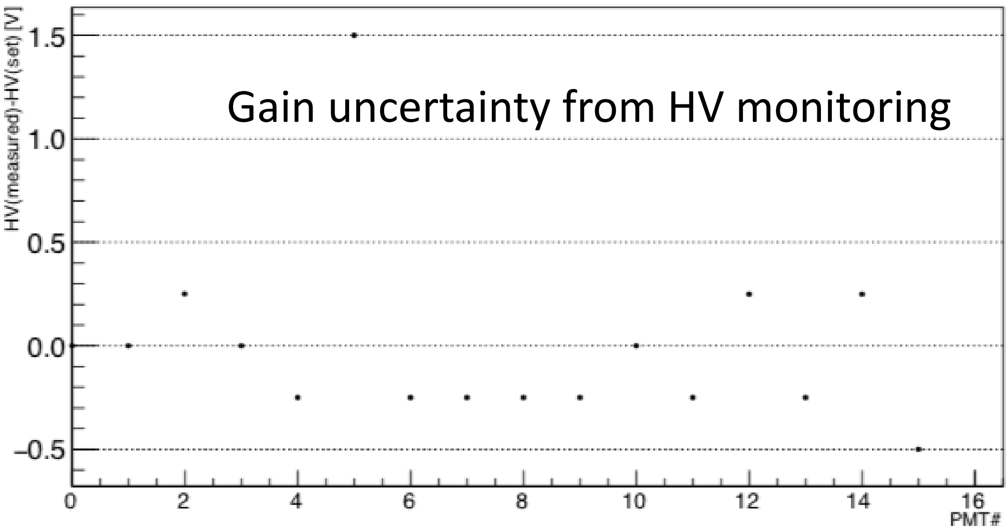
TAN厚 0.96±0.1 [r.l.]
W +0.02 ±0.02 [r.l.]
FCN 16.9

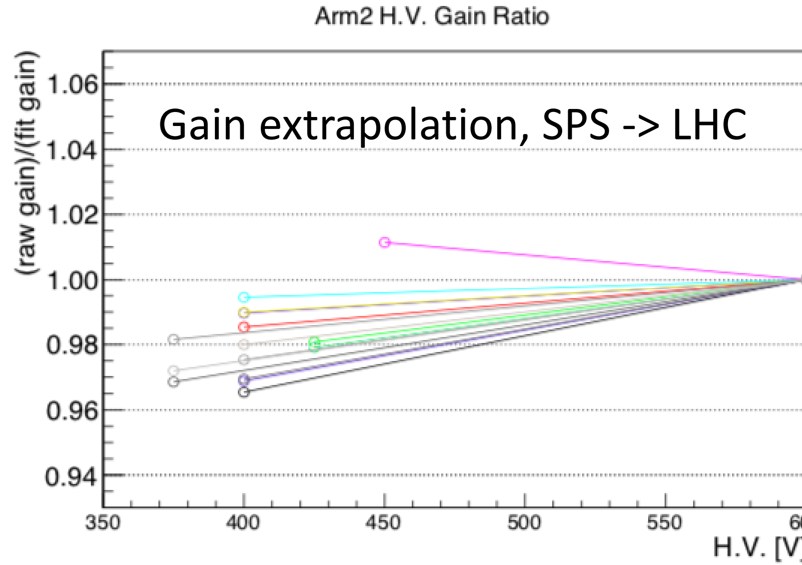
before new systematic error

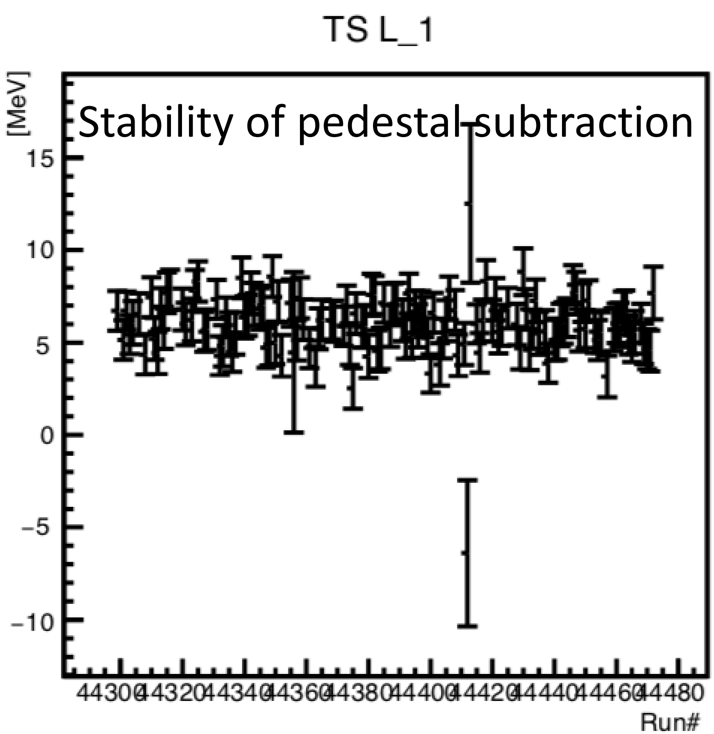
Matsubayashi's detail revisit on detector systematic errors

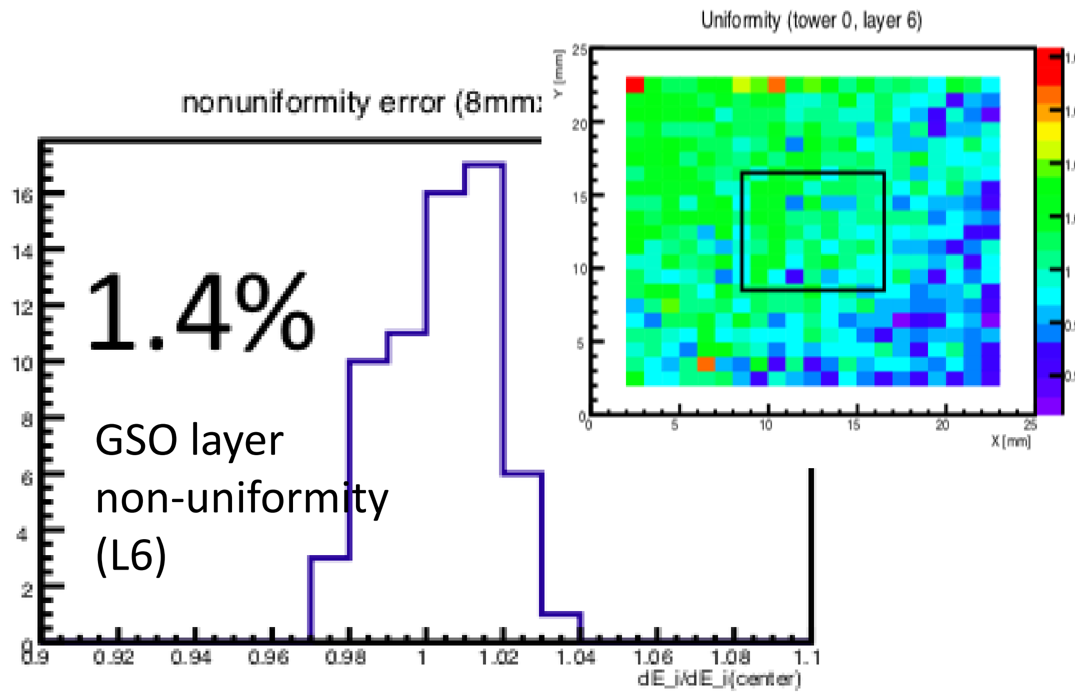
$$dE_i = \left\{(ADC)_i - (Pedestal)\right\} \times l \times C_i \times P_i \times G_i \times a_i$$

- ADC: ADC linearity (CAEN catalog +-0.1%)
- Pedestal: pedestal subtraction, stability
- l: Cable attenuation correction (+-0.5%)
- C_i : conversion factor (Revisit SPS2015)
- P_i: position dependence (non-uniformity)
- G_i: PMT gain (SPS->LHC), HV stability (slow data)
- a_i: temperature correction (correction constant)

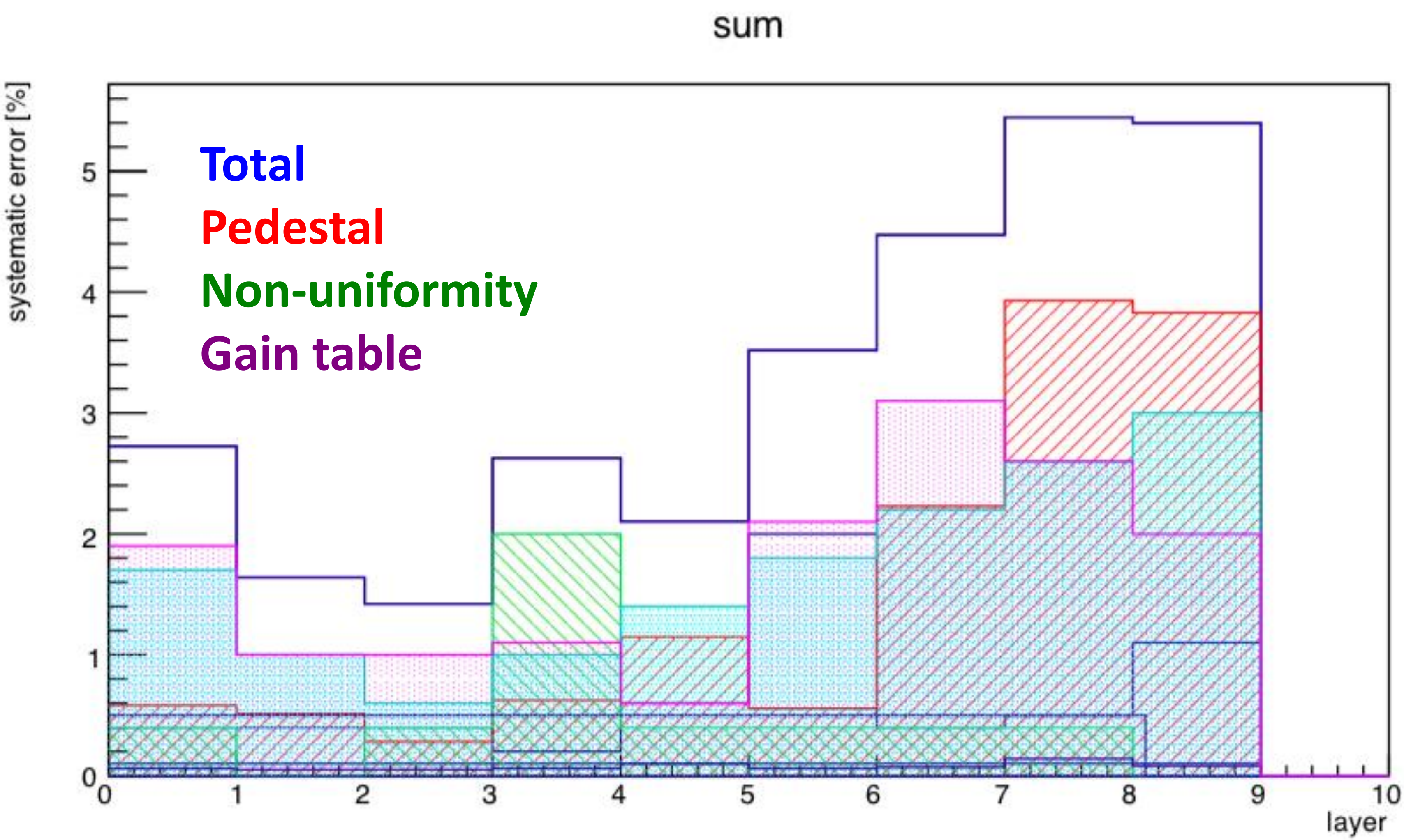

Gain uncertainty from HV monitoring
HV(measured)-HV(set) [V]
PMT#


Arm2 H.V. Gain Ratio
Gain extrapolation, SPS -> LHC
(raw gain)/(fit gain)
H.V. [V]

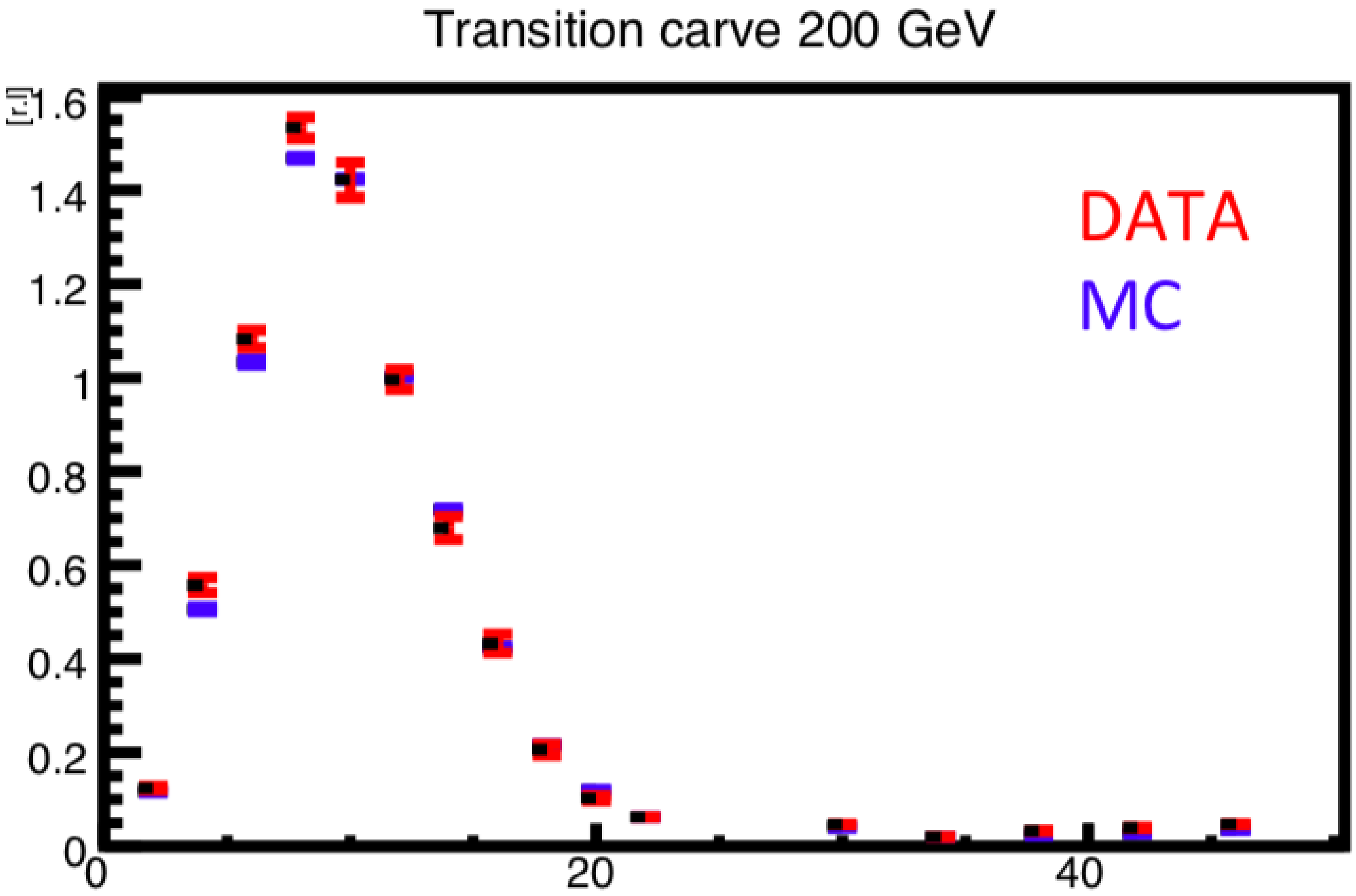

TS L_1
Stability of pedestal subtraction
[MeV]
Run#


nonuniformity error (8mm:
1.4%
GSO layer
non-uniformity
(L6)
dE_i/dE_i(center)
Uniformity (tower 0, layer 6)
Y [mm]
X [mm]

Layer-by systematic errors (tentative)



After Layer-by systematics considered



Data and MC almost overlapped within new systematics (red)
TAN thickness, W-layer thickness will be tuned again

To Do

- Tune MC (TAN, W-layer thickness) with updated detector systematic errors in $E\gamma<200$ GeV (fit data with α,β,γ as free)
- Validate fit and systematic errors in $E\gamma<500$ GeV (fit data with α,β,γ as penalty), check chi2
- Fit w/ and w/o LPM and show Delta chi2 (exclusion of no-LPM) and estimate size of LPM (introduce a LPM size parameter and fit it)
- Maybe add independent data set, Arm1 13 TeV or Arm2 8 TeV p-Pb and perform combined fit
- Make a journal paper and write PhD thesis in a year