Preliminary check on LHC 2022 Data

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LHCf Collaboration meeting

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Introduction

- Pedestal distributions: stability and noise
- Impact of electric noise on energy resolution
- Investigation on the origin of π^0 mass shift
- Estimation of beam projection on detector plane
- Preliminary photon spectrum from Run III data

Pedestal distributions

Motivation

We need to check pedestal distributions for at least 4 different reasons:
A) Estimate the pedestal level to be subtracted from the beam events
B) Check wether delayed gate subtraction reduce the amount of noise
C) Estimate the noise level to be introduced as smearing in simulation
D) Check if there is a mean offset between pedestal and beam events

Points A-C) can be studied using ***Pedestal*** events only
Points D) requires both pedestal and ***NoShower*** events

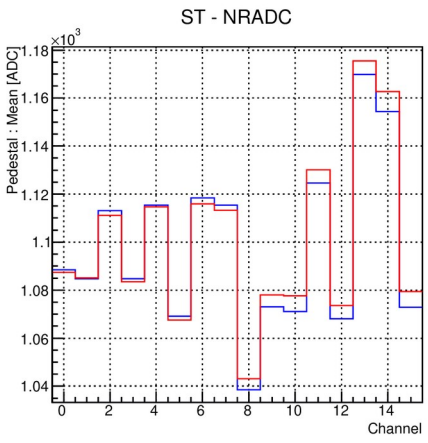
→ *NoShower* means beam events without shower
and in 2022 data it means ZDC-triggered events:
pedestal cleaning and *distribution fit* procedures
are applied since shower contamination is unavoidable

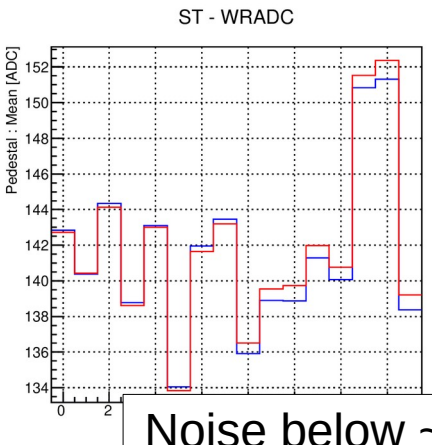
GSO: Mean and RMS without delayed gate subtraction

Run 80262-80346

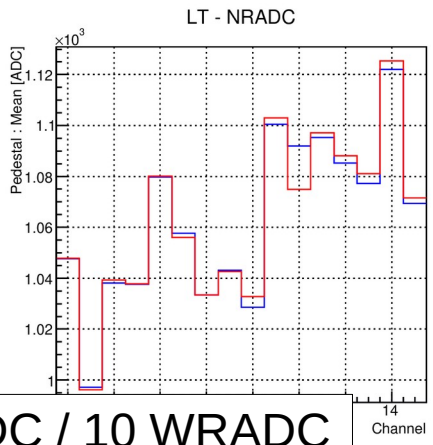
Pedestal events

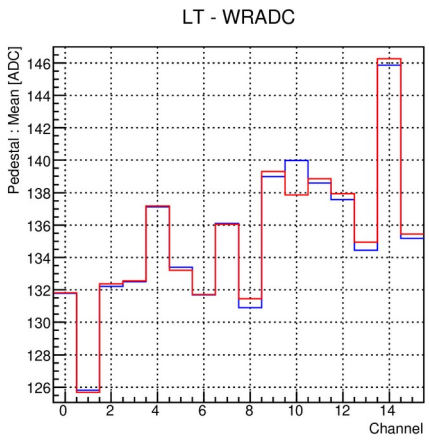
NoShower events



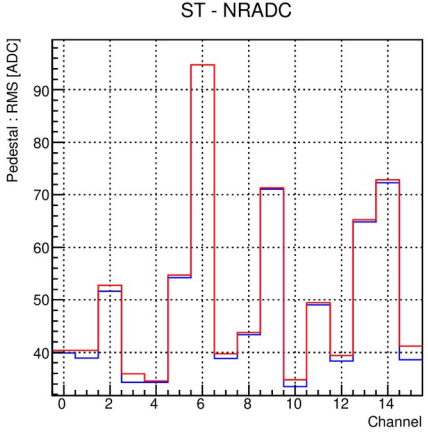


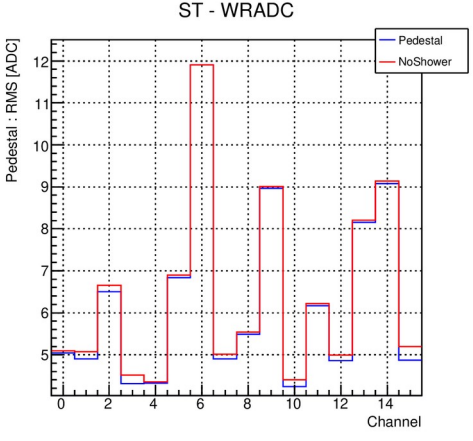
Mean



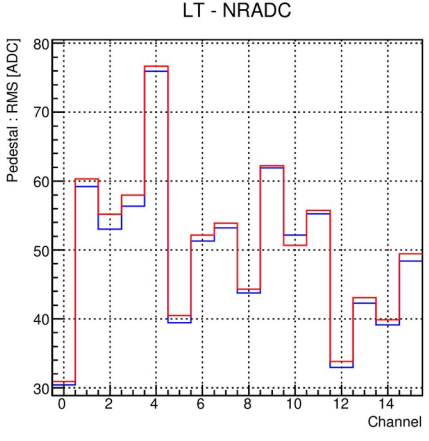


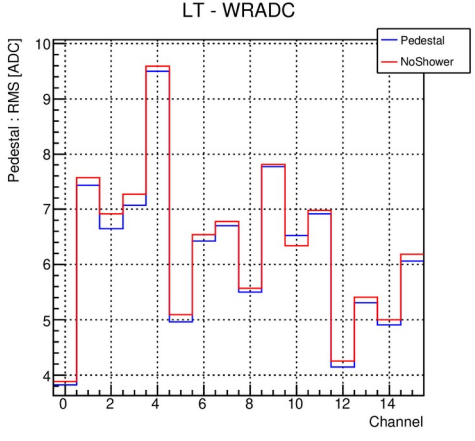
Noise below ~ 80 NRADC / 10 WRADC





RMS





GSO: Mean and RMS with delayed gate subtraction

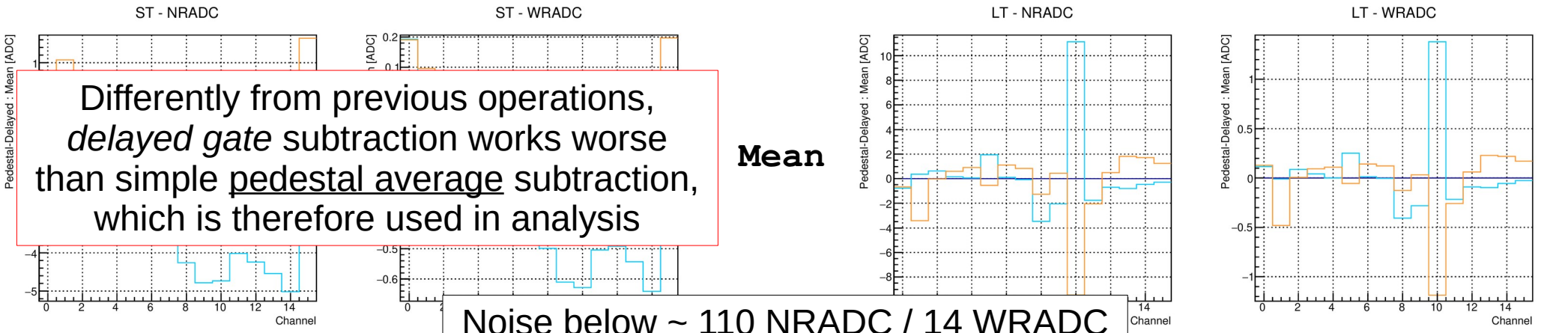
Run 80262-80346

Pedestal events

NoShower events

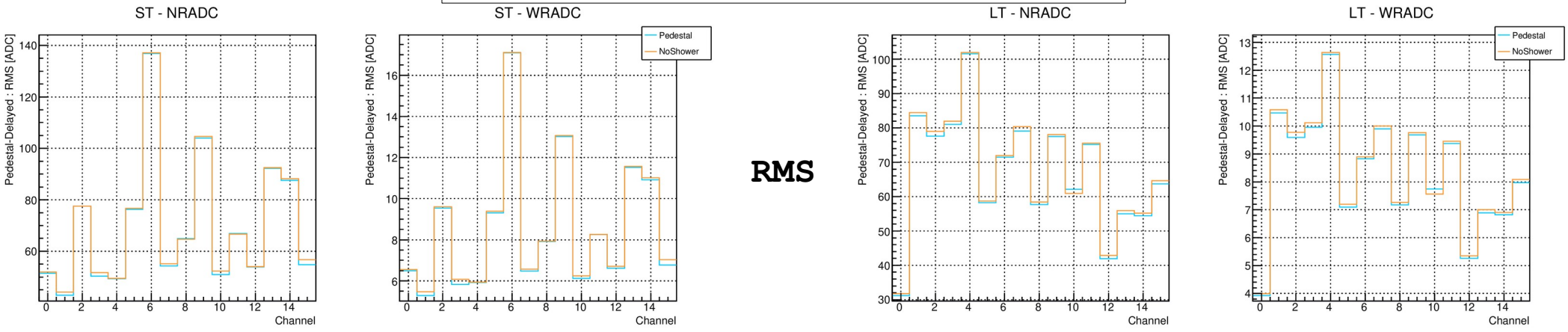
Differently from previous operations, *delayed gate* subtraction works worse than simple pedestal average subtraction, which is therefore used in analysis

Mean



Noise below ~ 110 NRADC / 14 WRADC

RMS



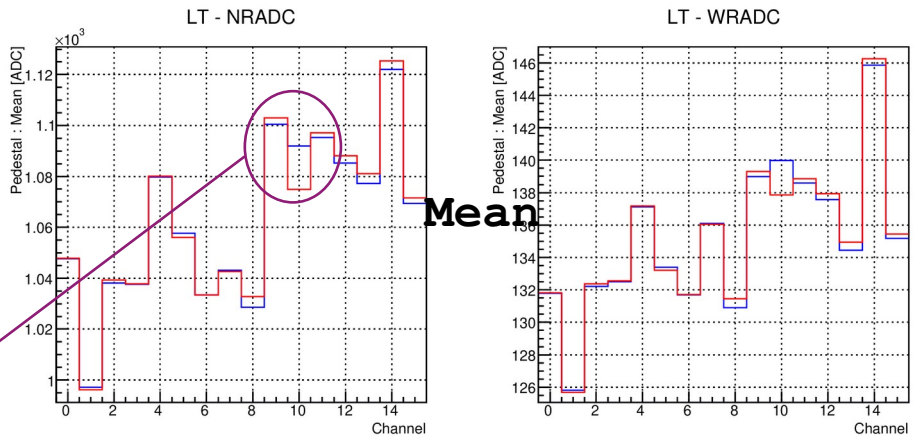
GSO: Mean offset between Pedestal and Beam events

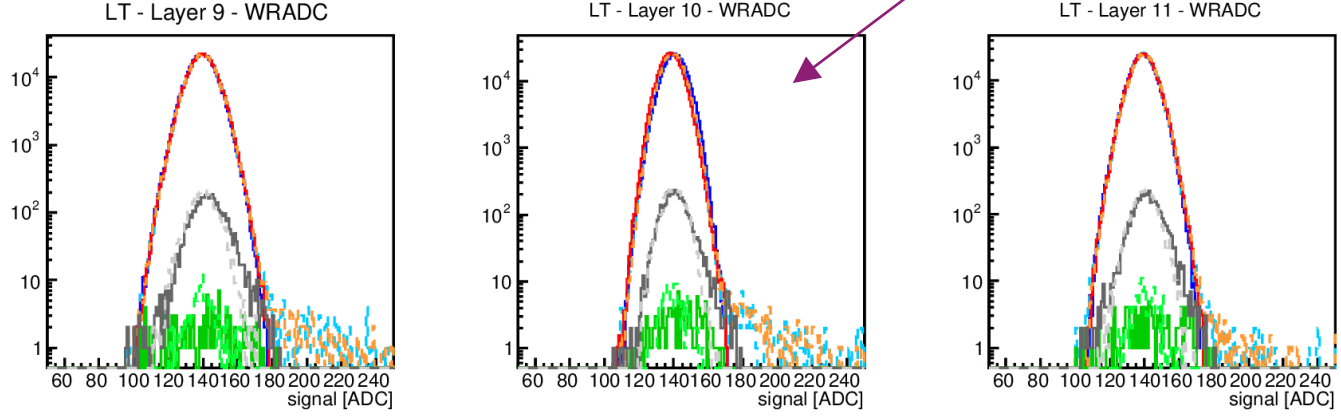
Run 80262-80346

Pedestal events

NoShower events

Differently from previous operations, Pedestal and Beam events have similar value of the average level in the absence of a shower





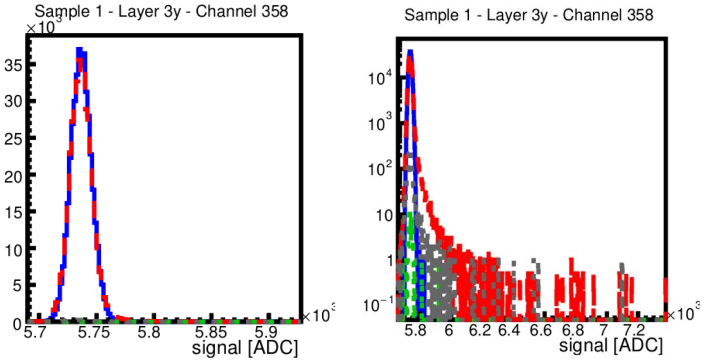
This residual offset, which is always below 18 NRADC, is subtracted event-by-event on a global way (not run-by-run)

Silicon: Mean and RMS

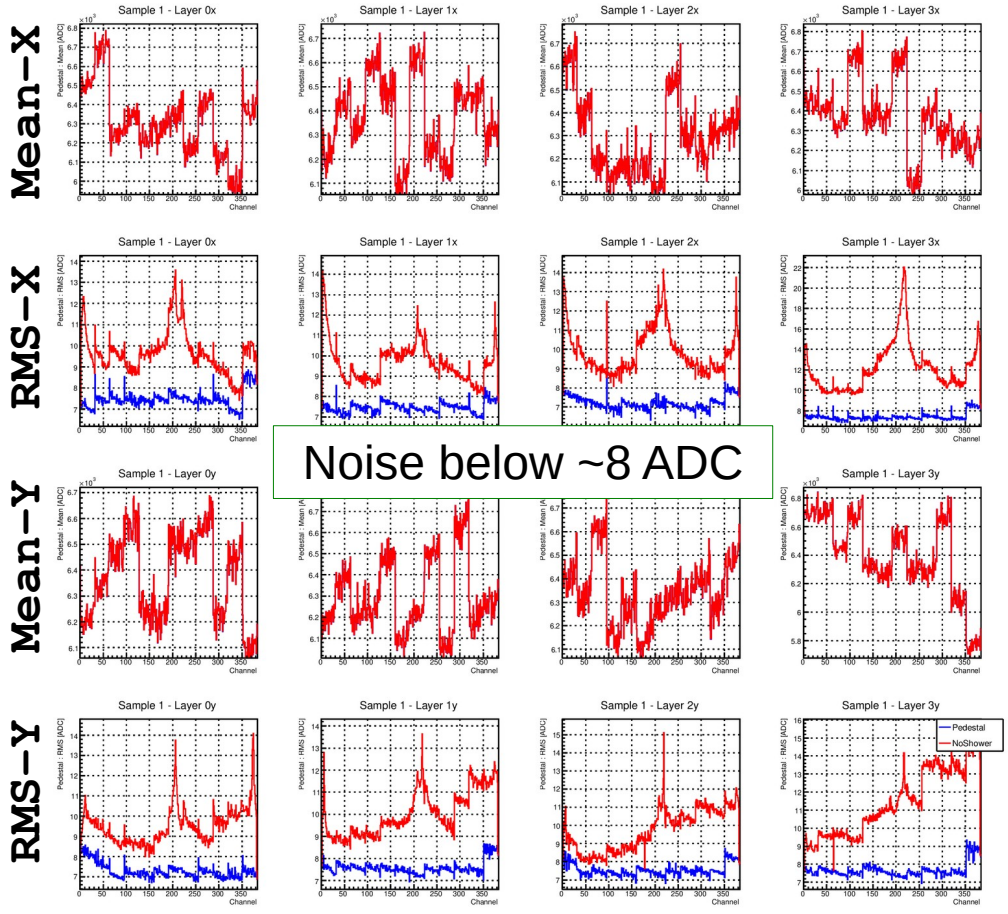
Run 80262-80346

Pedestal events

NoShower events



Contamination in *NoShower* events is more visible in silicon, but this information is not used and, in any case, it does not significantly impact on the average value.



Impact of electric noise

Noise level comparison

Layer	RMS (2015)	RMS (2022)
0	16.61	38.952
1	14.728	51.614
2	23.709	34.299
3	15.508	34.286
4	18.887	54.261
5	26.313	94.775
6	19.513	38.821
7	18.593	43.35
8	22.03	71.063
9	15.979	33.483
10	27.169	49.067
11	36.924	38.354
12	20.399	64.829
13	21.614	72.307

Small Tower

from pedestal-delayed gate

from pedestal

The larger noise level, together with the inability to use delayed gate subtraction, makes 2022 data more exposed to electronic noise, with possible implications on resolution of:

- *Energy*
- $L_{90\%}$

In the following, we consider only the impact on the reconstructed *Energy*, since the impact on $L_{90\%}$ should not be a problem if the noise effect is well reproduced in simulation smearing

Estimation

In order to estimate the impact of noise, we consider SPS simulation for 244 GeV electrons incident on 5x5mm^2 area on ST.

The simulation is reconstructed using the GSO gain factors from 2022 data, but with different energy smearing:

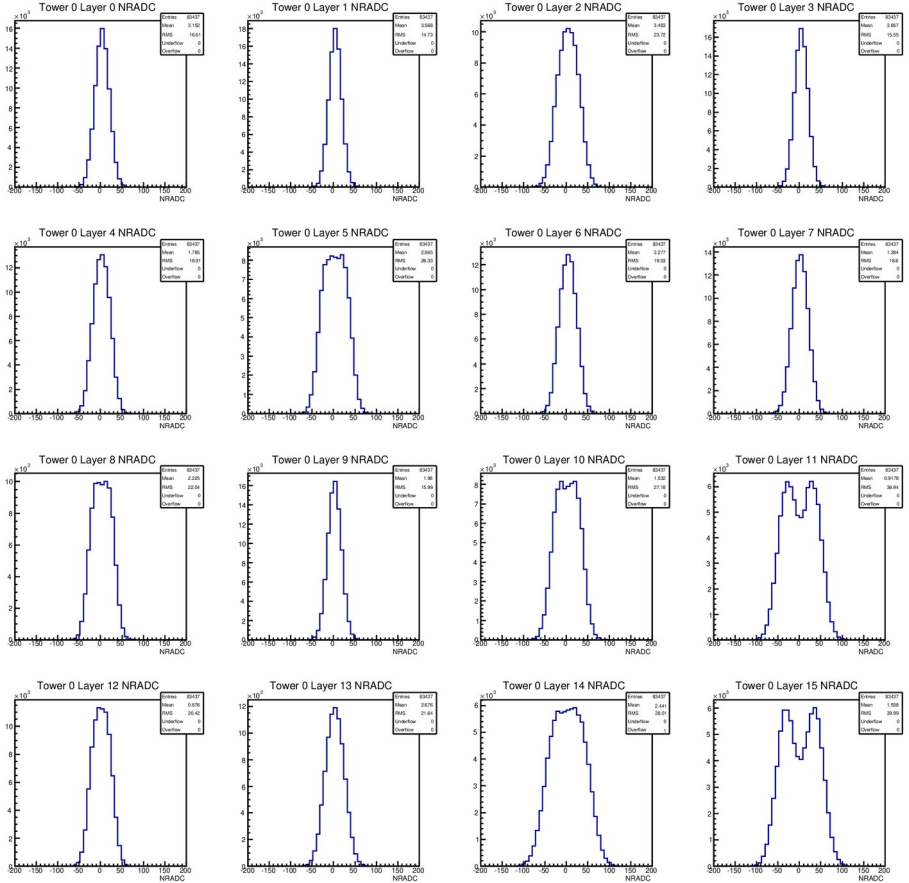
- without any kind of smearing
- smearing using 2015 noise
- smearing using 2022 noise

NB Smearing is applied by directly taking the pedestal events acquired during operations in order to consider correlation.

Smearing

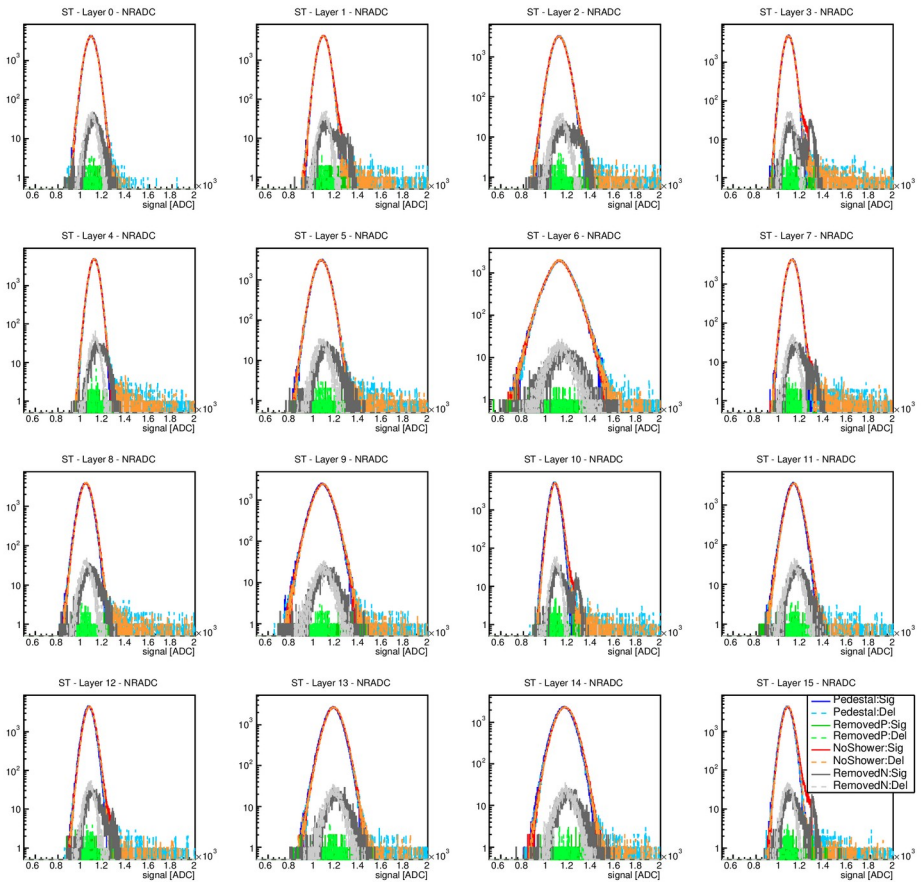
Pedestal of TS NRADC in 2015

from pedestal-delayed gate



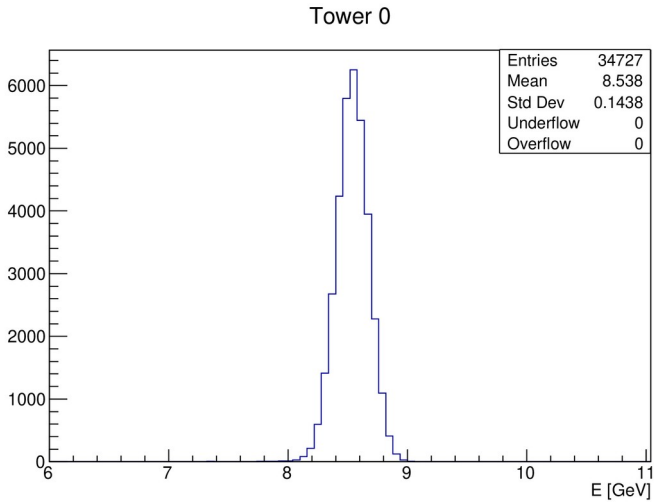
Pedestal of TS NRADC in 2022

from pedestal



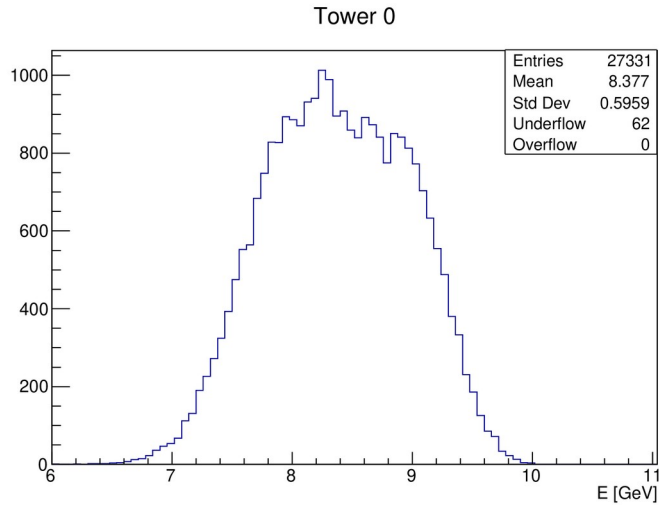
Result

No Smearing



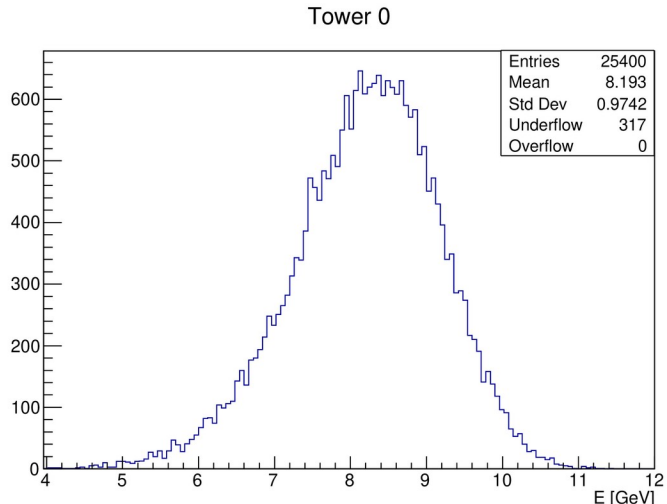
Intrinsic resolution
$\sigma_E/E = 0.144/8.538 = 1.7\%$

Smearing 2015



Resolution
$\sigma_E/E = 0.596/8.377 = 7.1\%$

Smearing 2022



Resolution
$\sigma_E/E = 0.974/8.193 = 12\%$

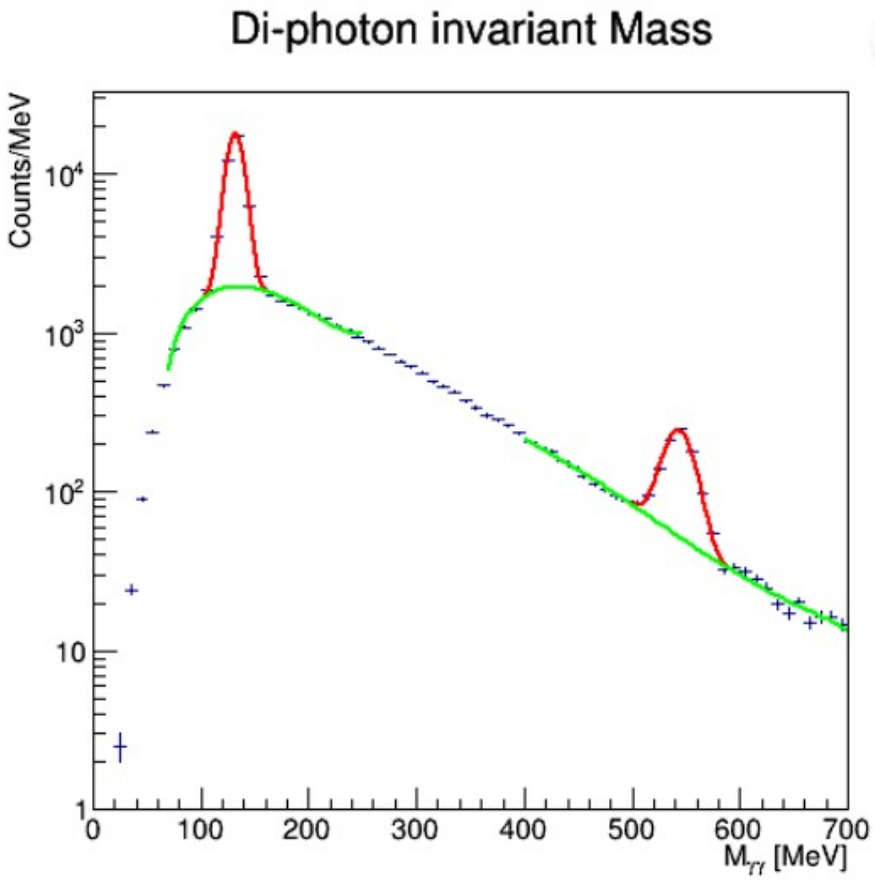
Noise Contribution (as sumdE)
$b = \sqrt{0.596^2 - 0.144^2} = 0.578$ GeV

NB: In SPS 2022, noise was negligible because RMS was 5 times smaller and gains 15 times larger

Noise Contribution (as sumdE)
$b = \sqrt{0.974^2 - 0.144^2} = 0.963$ GeV

Investigation
on the origin of π^0 mass shift

Motivation



Giuseppe found a 11.25% shift in the Type I invariant mass, which is a rather large value...

This effect was investigated by applying a narrow cut in the reconstructed energy ([500, 550] GeV) and comparing the average layer-by-layer energy deposit between 2015 and 2022 Data

The same study was repeated for simulations with and without an artificial energy scale shift

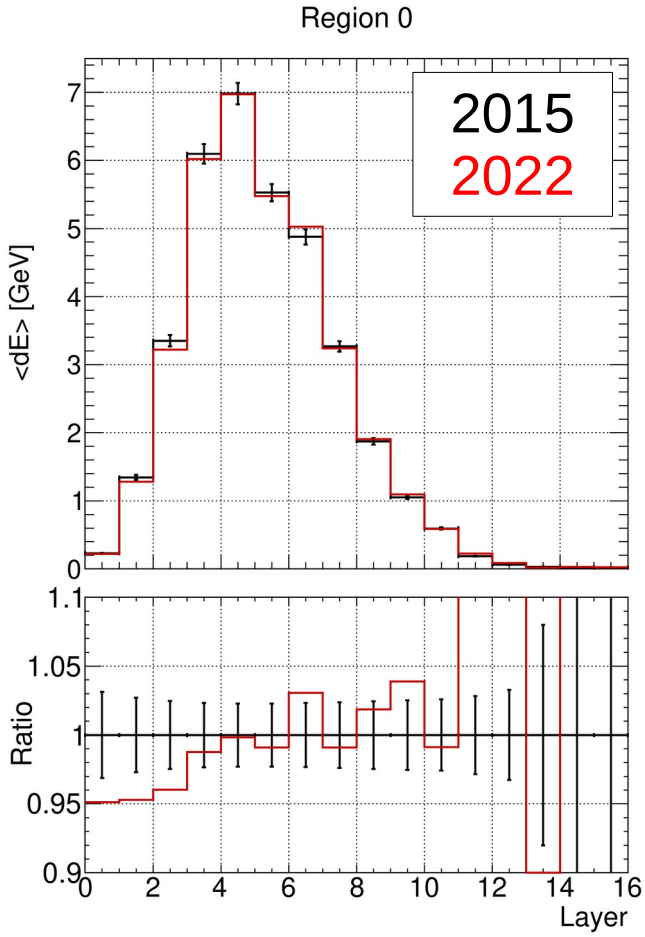
Study

Data

Simulation

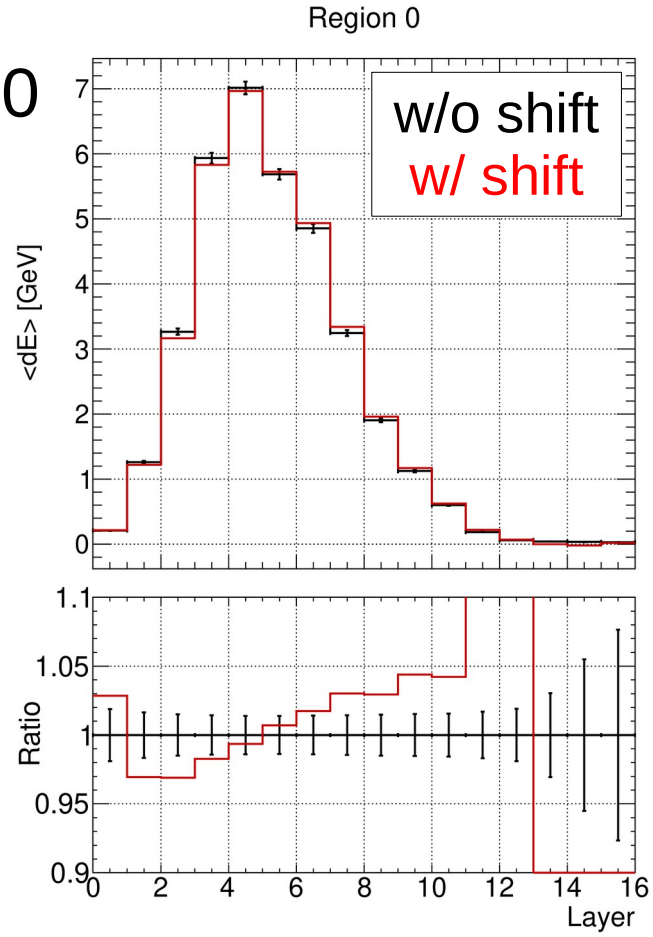
Average Longitudinal Profile

Small Tower – Region 0



Excluding layer 0 (beam halo effect?), considering the more limited statistics in Data, the residuals on GSO layer gain calibration, and the absence of temperature corrections, the trend is compatible

The 11.25% shift seems due mostly to global factor rather than a layer-by-layer gain calibration effect.

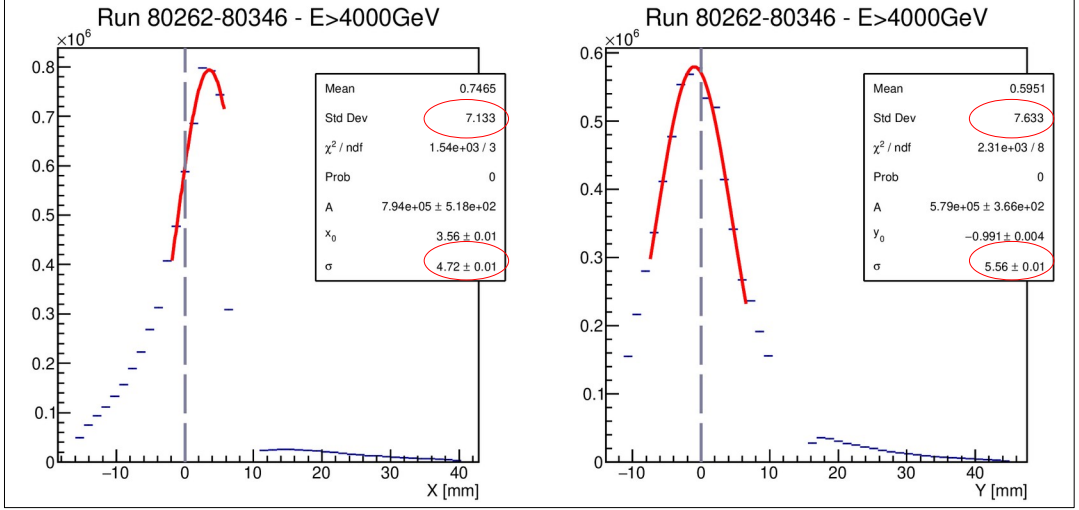


Estimation
of beam center position

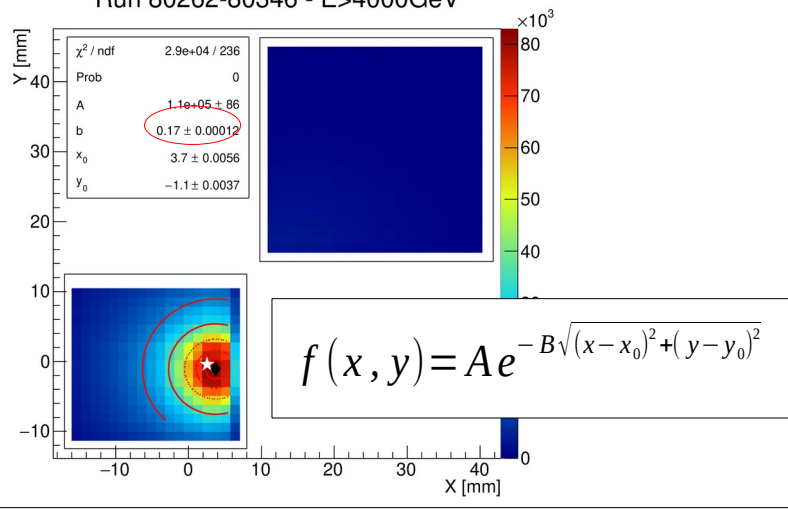
Method

Historically, beam center position is estimated
by comparing two different determination methods

Gaussian fit on 1D X and Y Projection

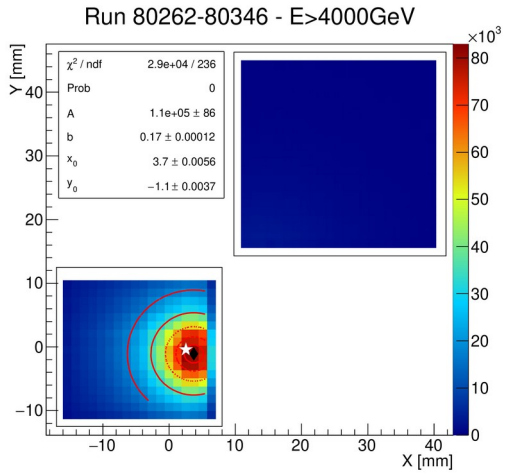


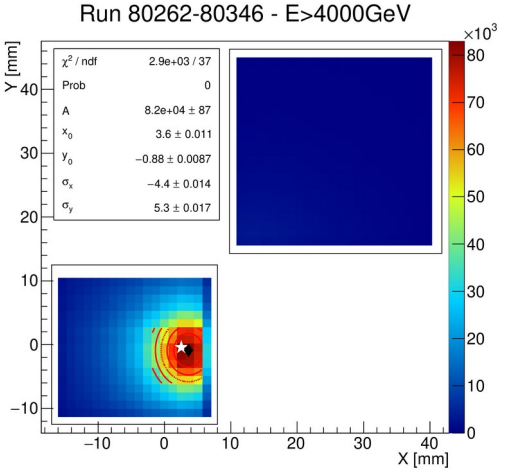
Exponential fit on 2D distribution



It is interesting to notice that the two methods differ not only because of the function,
but also because of the implicit assumption that x and y width can or cannot be different

Update of 2D function





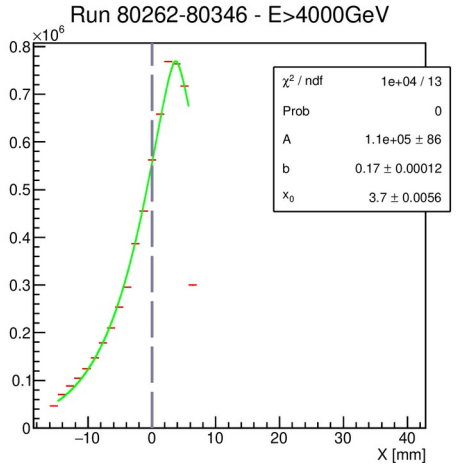
Exponential

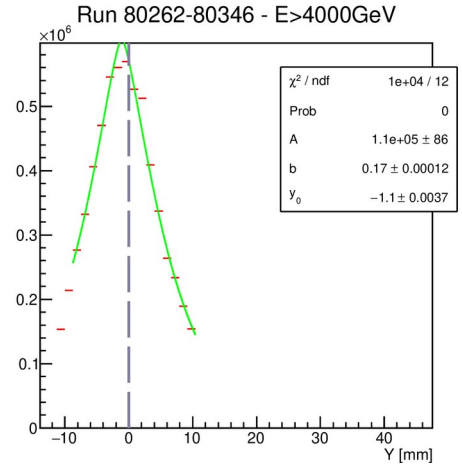
$$f(x,y) = Ae^{-B\sqrt{(x-x_0)^2+(y-y_0)^2}}$$

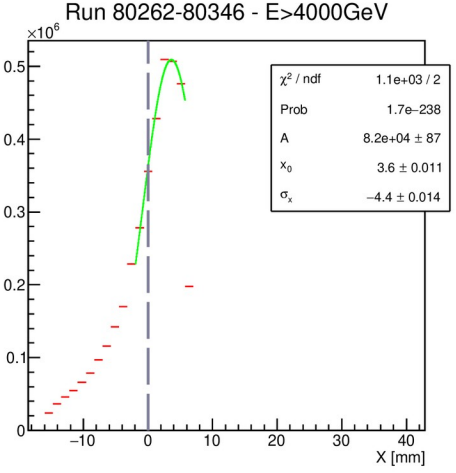
By looking at the projection I decided to update the 2D function to a *double gaussian*

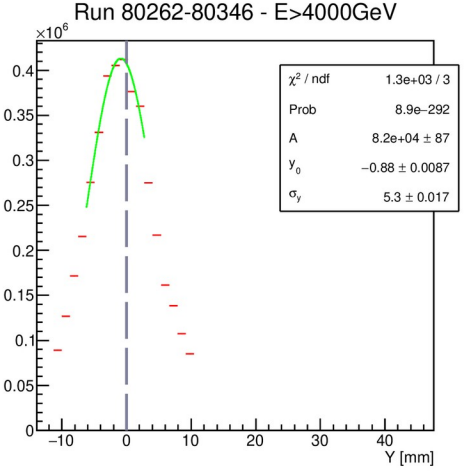
Double gaussian

$$f(x,y) = Ae^{-\frac{(x-x_0)^2}{2\sigma_x^2}} e^{-\frac{(y-y_0)^2}{2\sigma_y^2}}$$







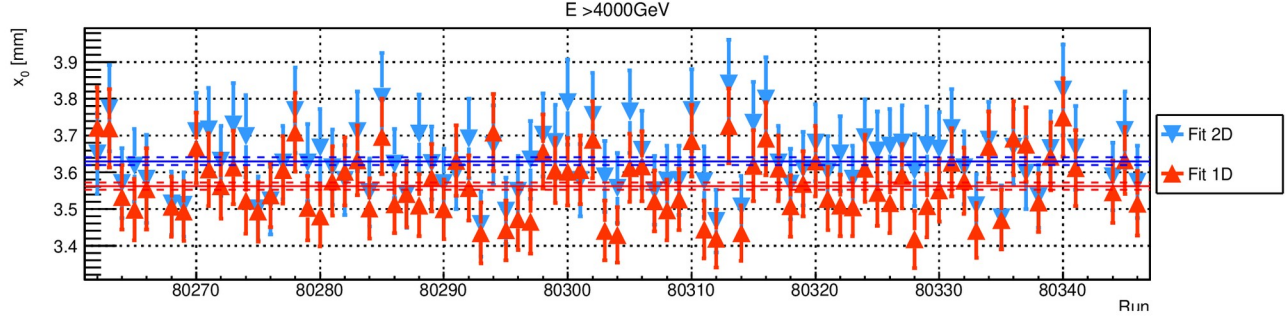


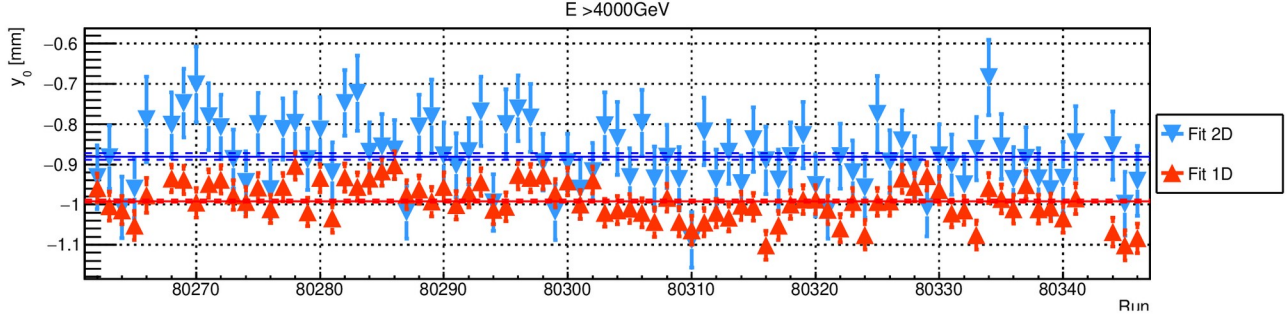
Run-by-run stability

Run-by-Run result is mostly **stable** inside each of the five large data set

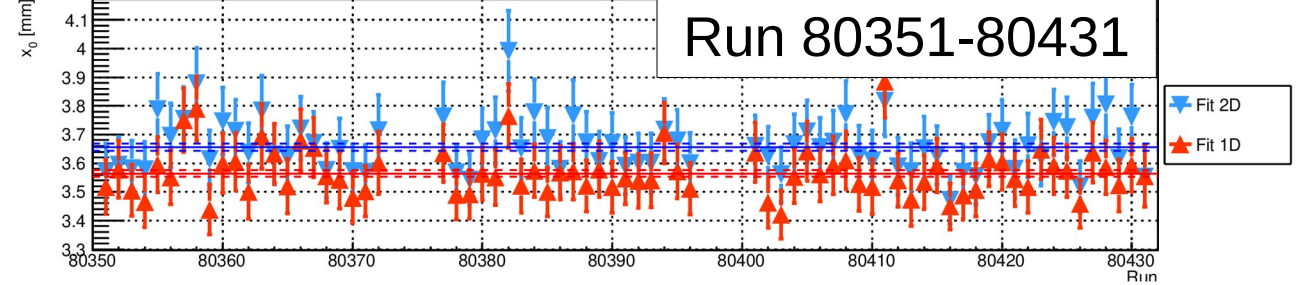
A global beam center parameter for each data set is enough

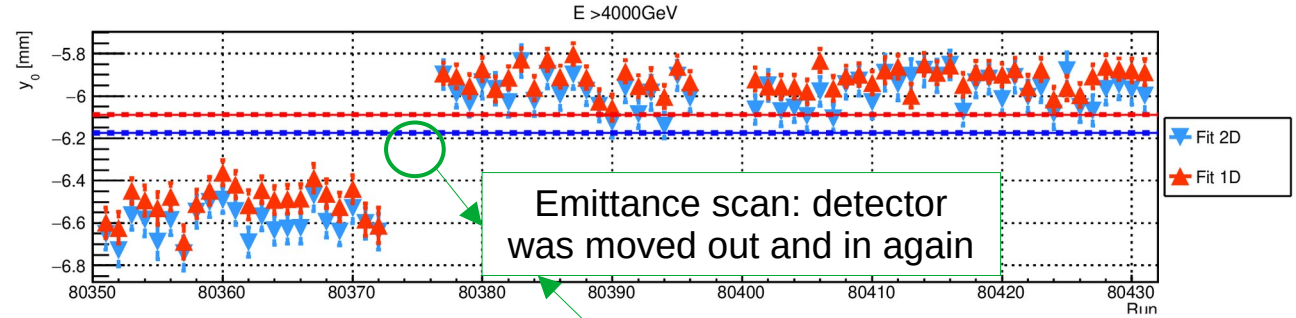
Run 80262-80346



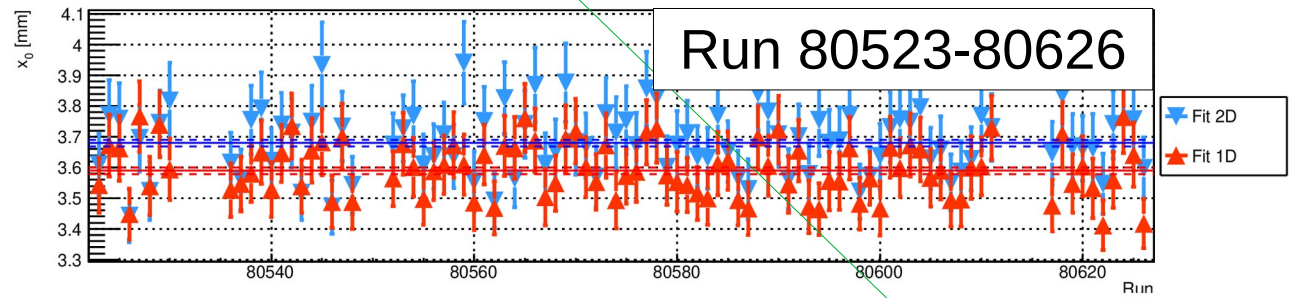


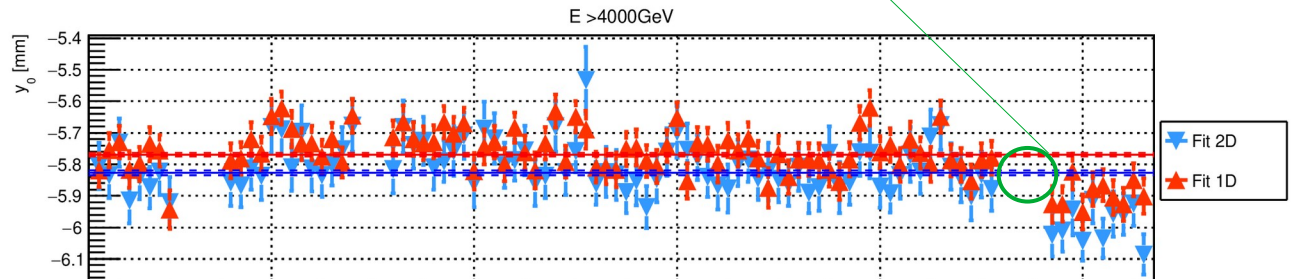
Y offset during 2nd and 4th large data set





Emittance scan: detector was moved out and in again





Something happened during emittance scan: beam change or manipulator offset?

Run 80351-80431 must be divided in two:

- Run 80351-80372
- Run 80377-80431

Run 80523-80626 can be kept as it is since it is just a 0.1 mm offset acting on just 10 runs

Preliminary Arm2 Beam Center Position

Run	80262-80346	80351-80372	80377-80431	80434-80520	80523-80626	80635-80646
x_0 [mm]	$3.630^{+0.231}_{-0.160}$	$3.660^{+0.248}_{-0.216}$	$3.654^{+0.236}_{-0.236}$	$3.650^{+0.174}_{-0.184}$	$3.680^{+0.250}_{-0.212}$	$3.517^{+0.156}_{-0.229}$
y_0 [mm]	$-0.880^{+0.153}_{-0.190}$	$-6.602^{+0.100}_{-0.124}$	$-5.985^{+0.077}_{-0.074}$	$-0.971^{+0.125}_{-0.205}$	$-5.827^{+0.058}_{-0.070}$	$-0.954^{+0.138}_{-0.470}$

These numbers must be updated after fixing two different problems:

- correct and uniform library for (x,y) projection along different z
- update GSO gain factor after completing calibration procedure

Preliminary photon spectra

Motivation

Main motivations are:
- INFN milestone for this year!
- Test of the updated library
- Check overall data quality:
  - Agreement with 2015 result
  - Statistics increase wrt 2015

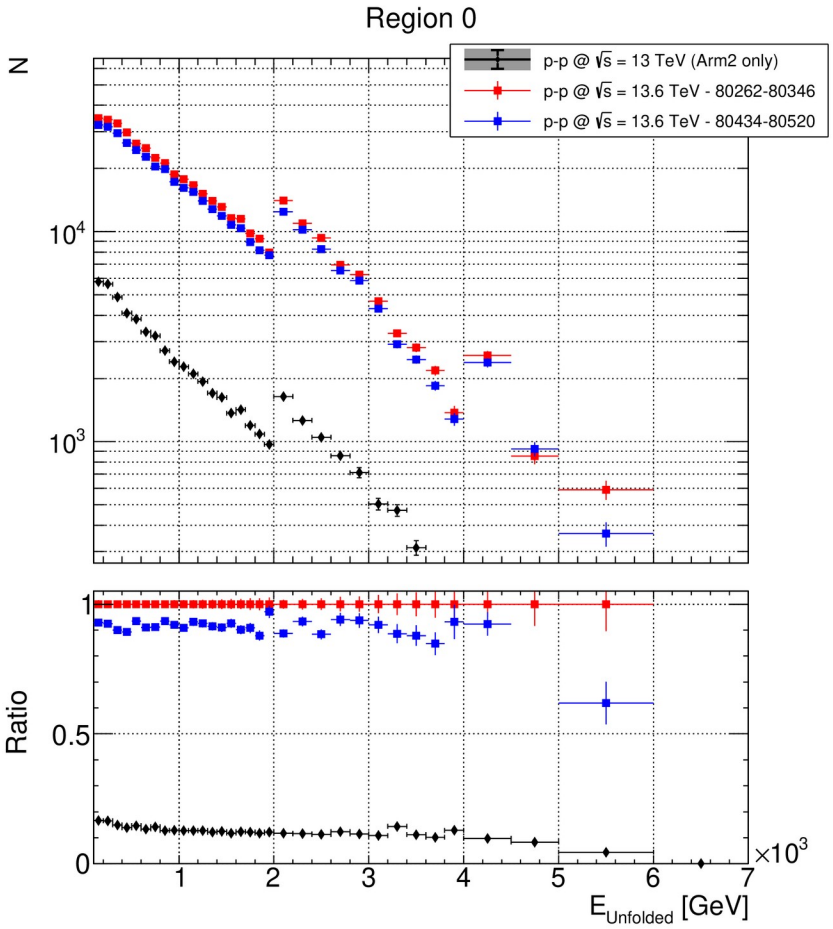
Main steps of the analysis:
- Beam background correction
  - ✔ PID correction
- ✔ Unfolding (+ Multihit correction)
- Decay correction

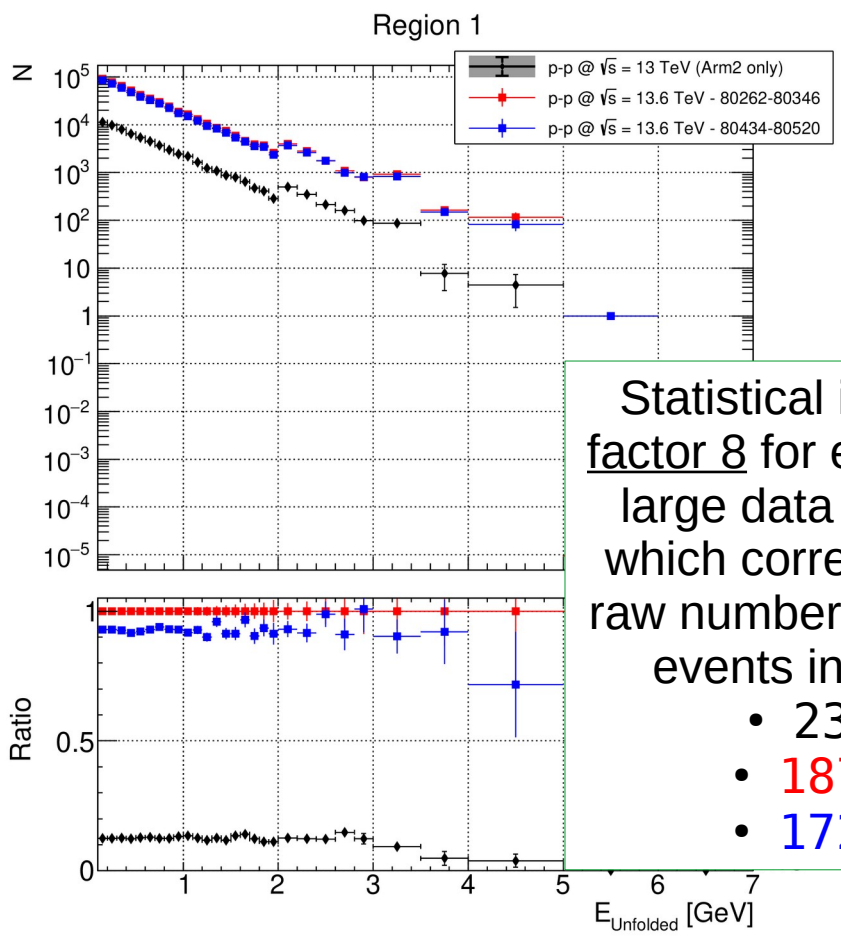
Main approximations wrt 2015:
- Using pp@13 TeV simulations
- Using temporary gain factors (but correcting for 11.25% shift)
- Inconsistent (x,y) projection over z

NB: Using two large data set with Arm2 in nominal detector position events

NB: Selecting only L2TShower events

Raw Counts

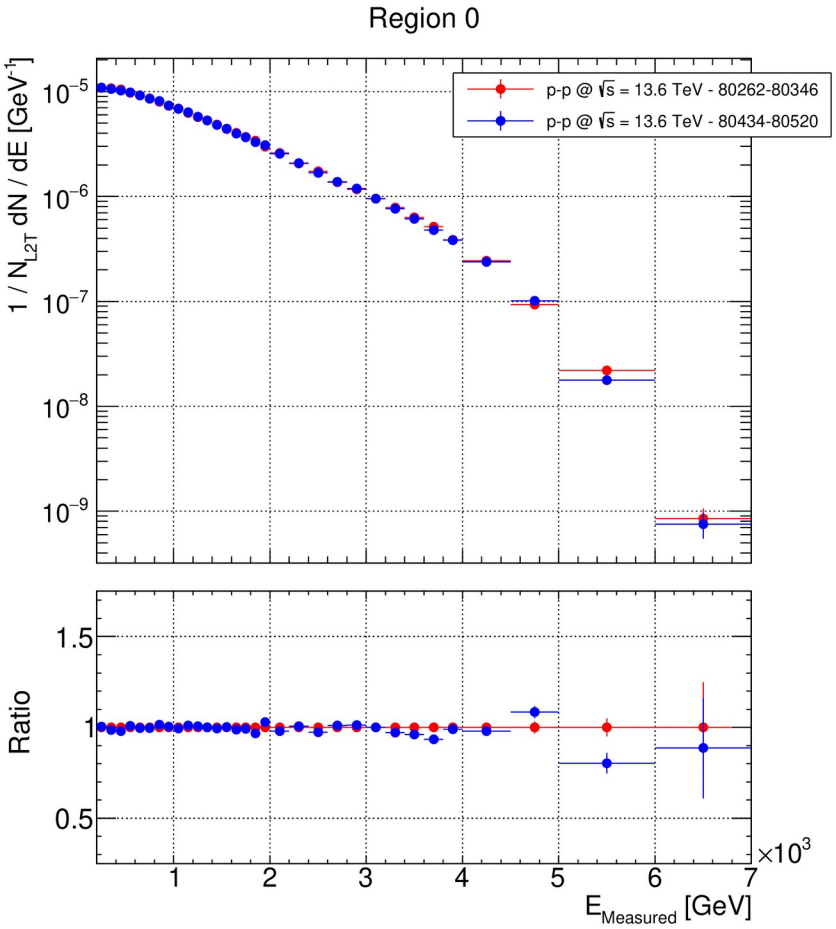


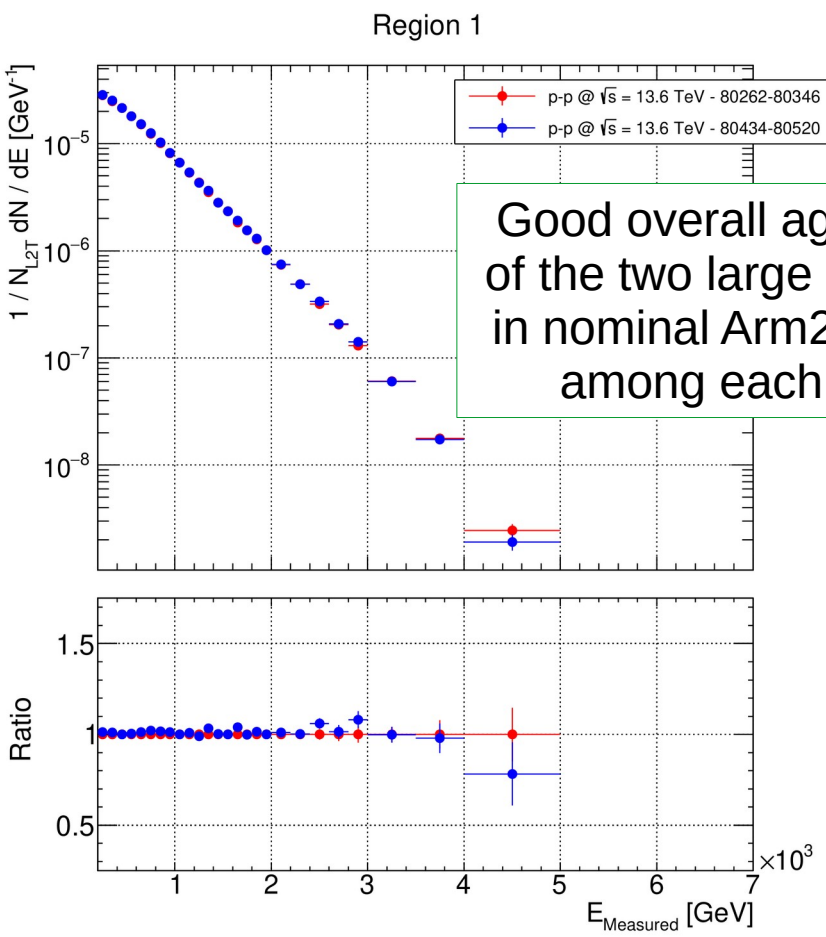


Statistical increase by a factor 8 for each of the two large data set wrt 2015, which corresponds to the raw number of L2TShower events in each case:

- 2375201
- 18773254
- 17214681

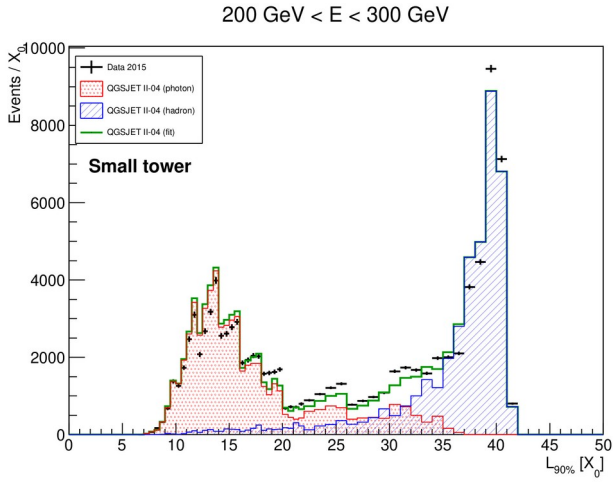
Raw distributions

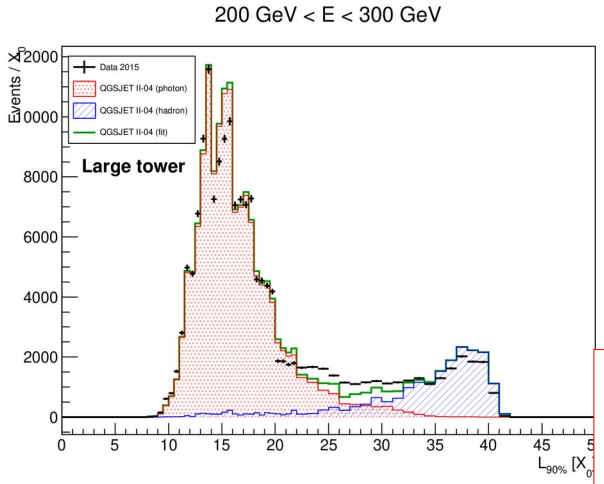


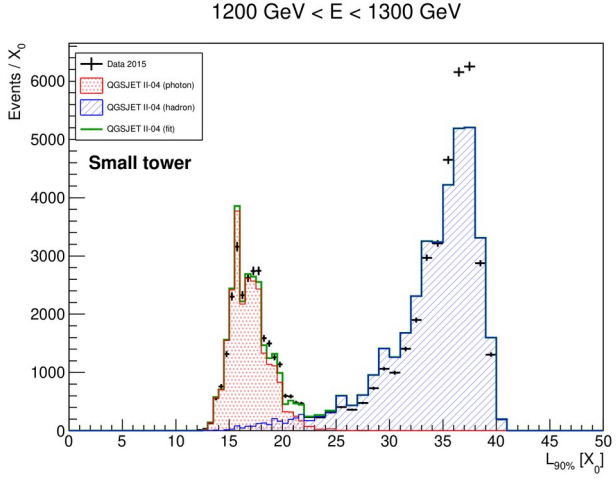


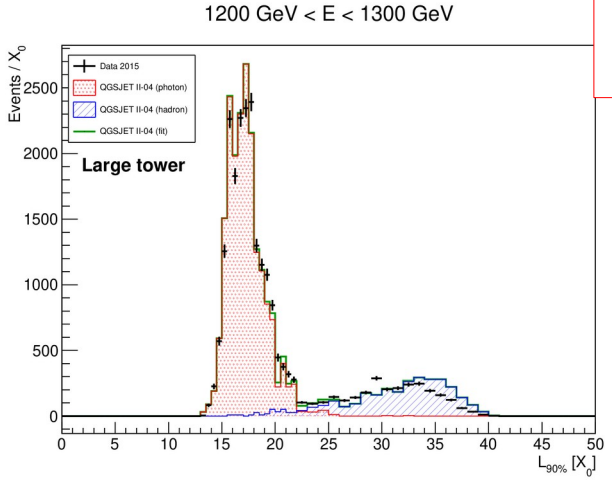
Good overall agreement of the two large data sets in nominal Arm2 position among each other

PID correction





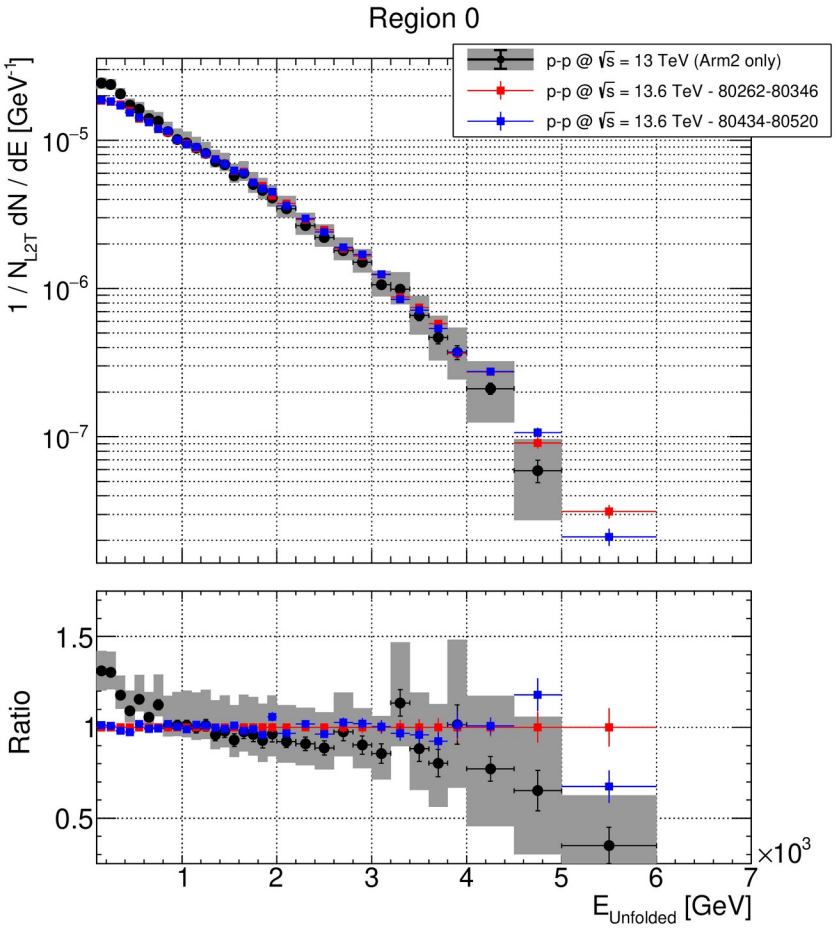


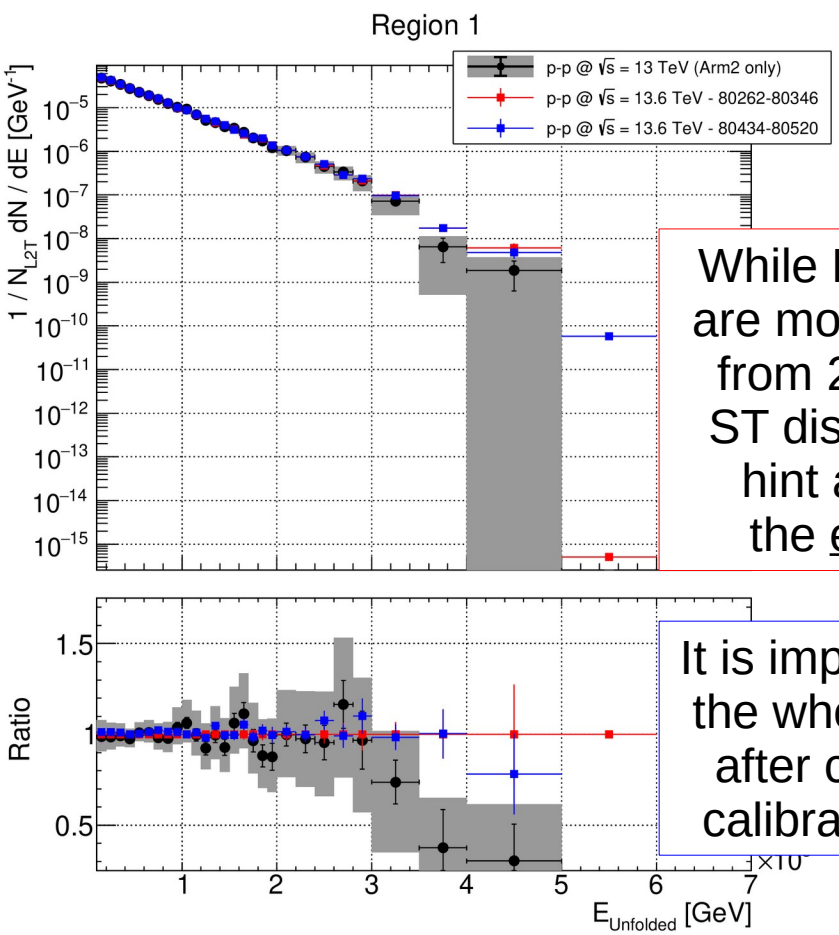


Problematic data-MC agreement in the hadron sector of L90% may hint incomplete calibration of some of the GSO gain factors

Unfolded distributions (After PID&MH corrections)

Data from 2022 with stat error only





While LT distributions are mostly compatible from 2015 to 2022, ST distributions may hint an issue with the <u>energy scale</u>

It is important to repeat the whole comparison after completing the calibration procedure

TODO List

TODO List

From most urgent to least urgent

- Start simulations relative to pp@13.6 TeV!
  - Complete GSO (and silicon) calibration
  - Fix (x, y) projection over z in the library
- Re-estimate beam center for each data set
- Develop photon analysis in the new library
- Estimate integral luminosity for each data set

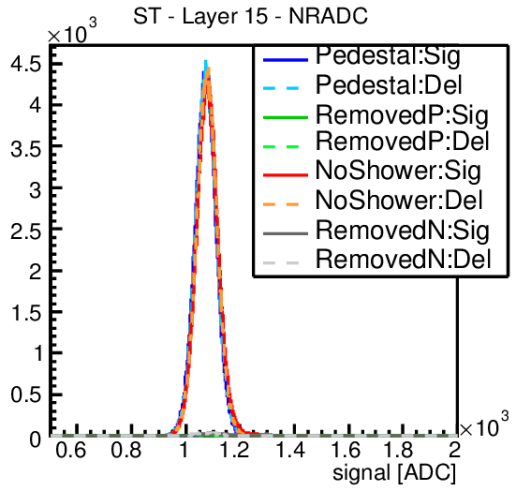
Check Type I and Type II invariant mass as a function of the energy

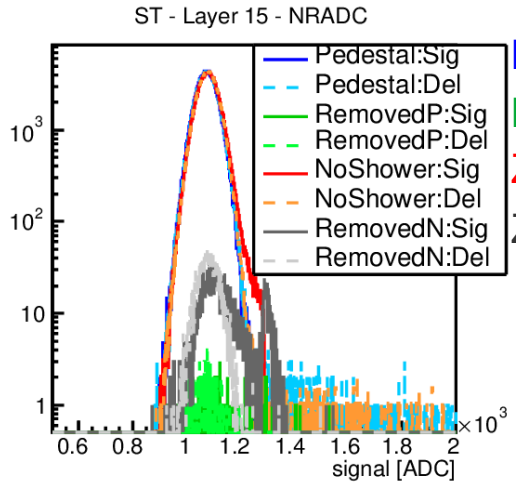
Implement silicon electronics calibration procedure (and run it)

Back up

An example

Run 80262-80346



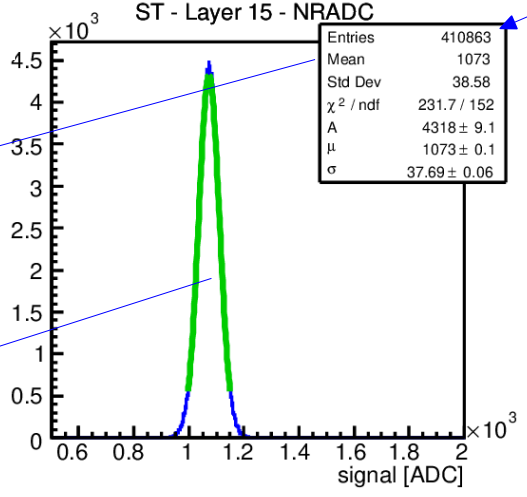


Pedestal events accepted by iterative procedure

Pedestal events removed by iterative procedure

ZDC-trig events accepted by iterative procedure

ZDC-trig events removed by iterative procedure

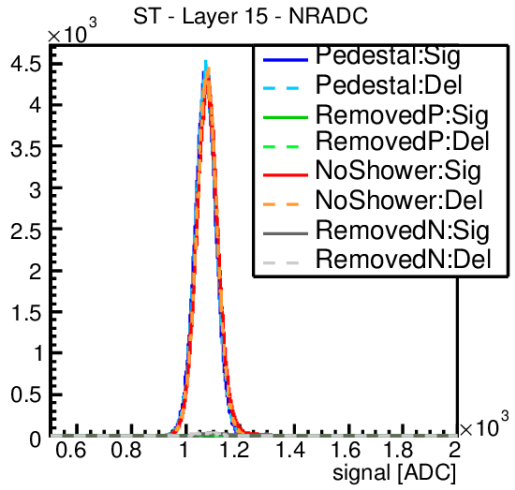


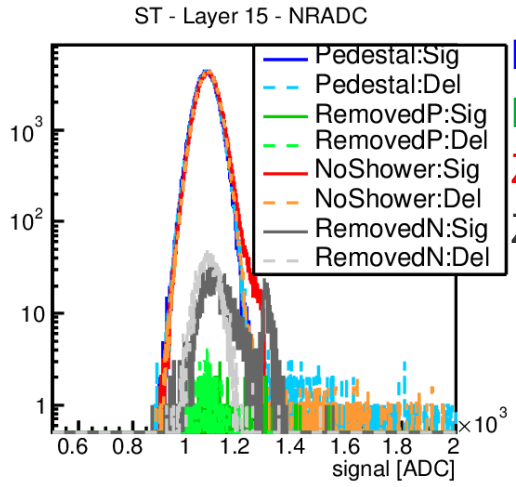
Pedestal average subtracted from beam events (real computation is run-by-run)

Event-by-Event pedestal randomly used for pedestal smearing in simulations

An example

Run 80262-80346





Pedestal events accepted by iterative procedure

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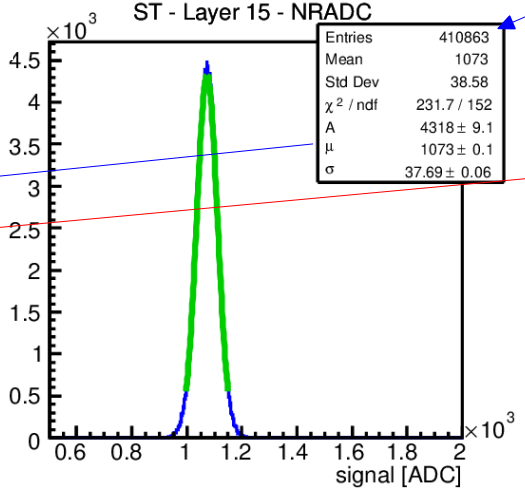
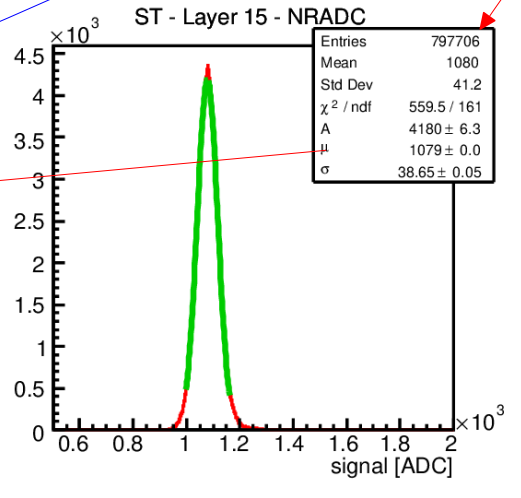




The difference between these numbers is used to correct for possible offset between pedestal and beam-crossing events

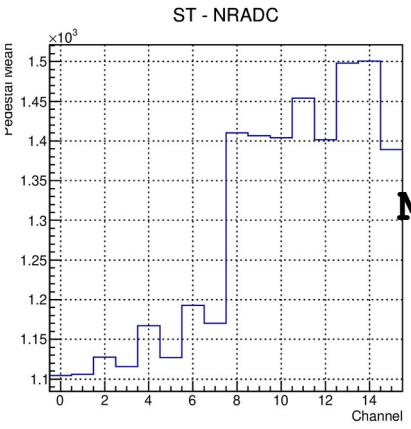
NB Fit converges even if quality is so-so: the good point is that fit and statistical mean are very similar to each other

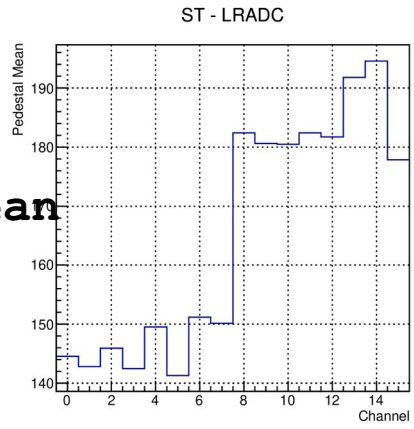
Noise in SPS2022 and LHC2022

Pedestal of TS NRADC in SPS2022

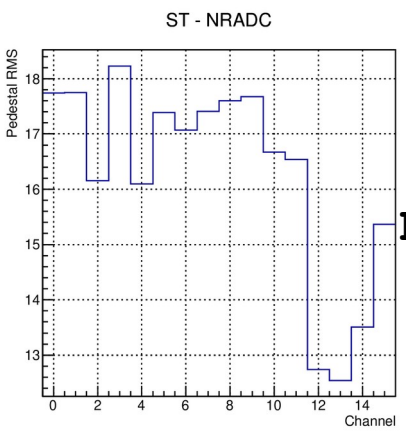
from pedestal

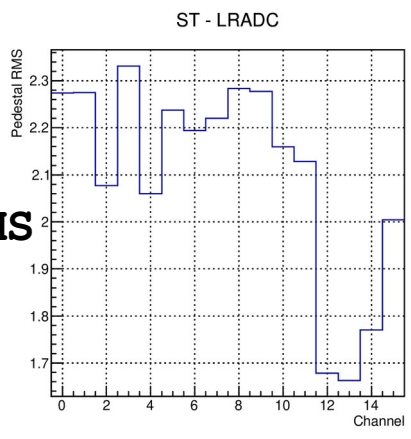
Mean





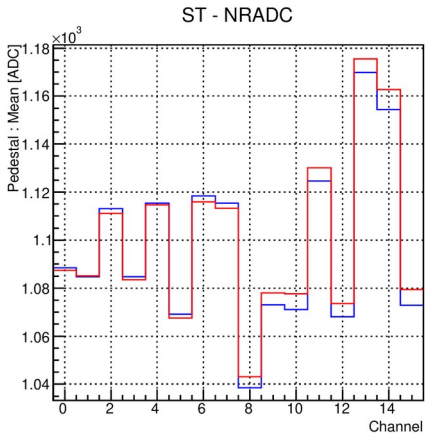
RMS

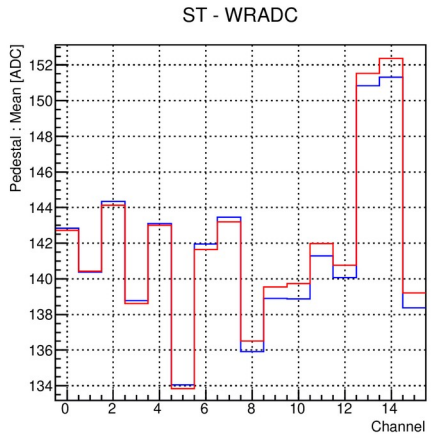


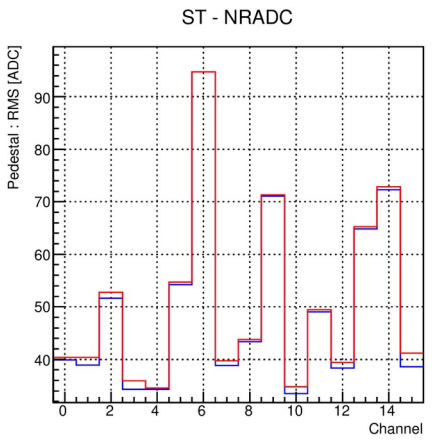


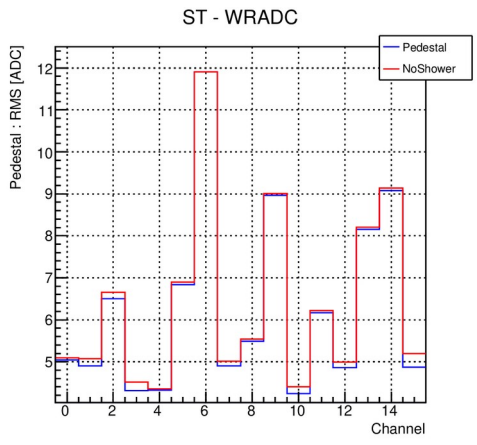
Pedestal of TS NRADC in LHC2022

from pedestal





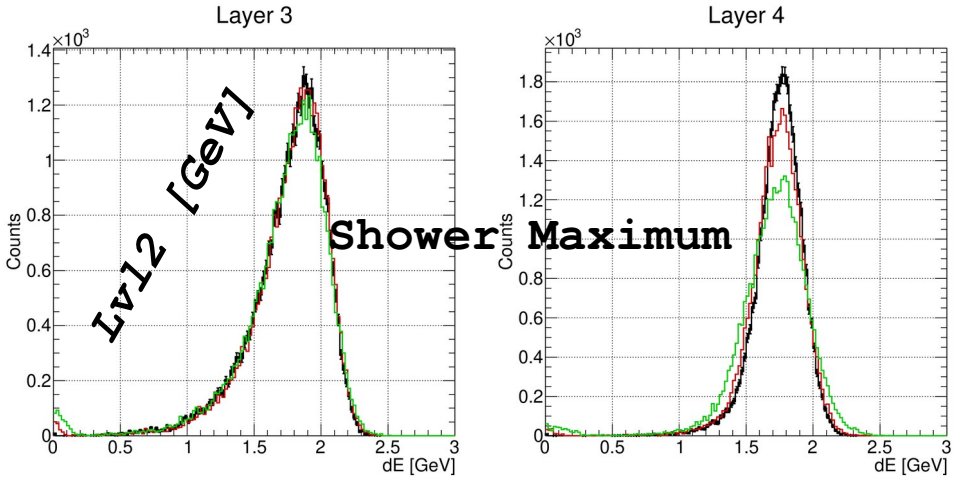


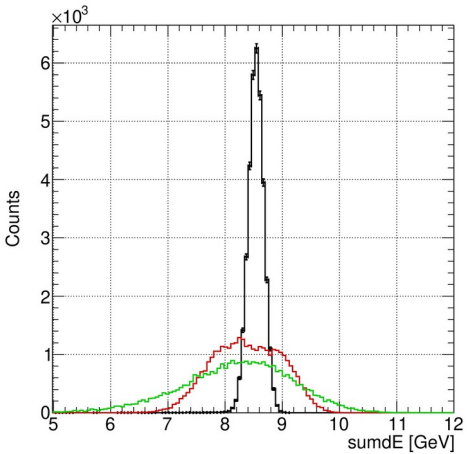


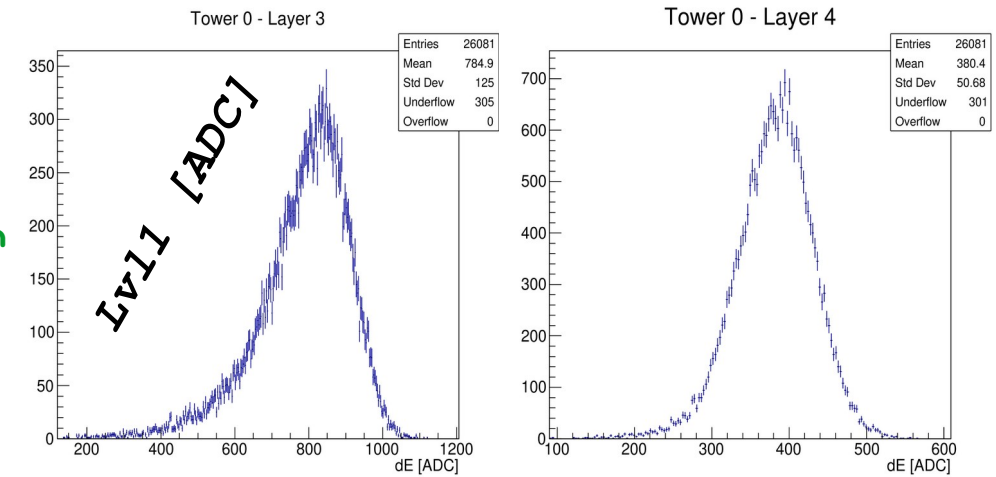
Noise Comparison

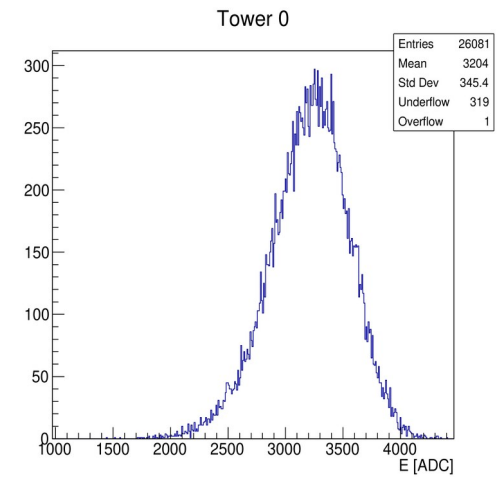
No smearing
Smearing 2015
Smearing 2022

Smearing 2022

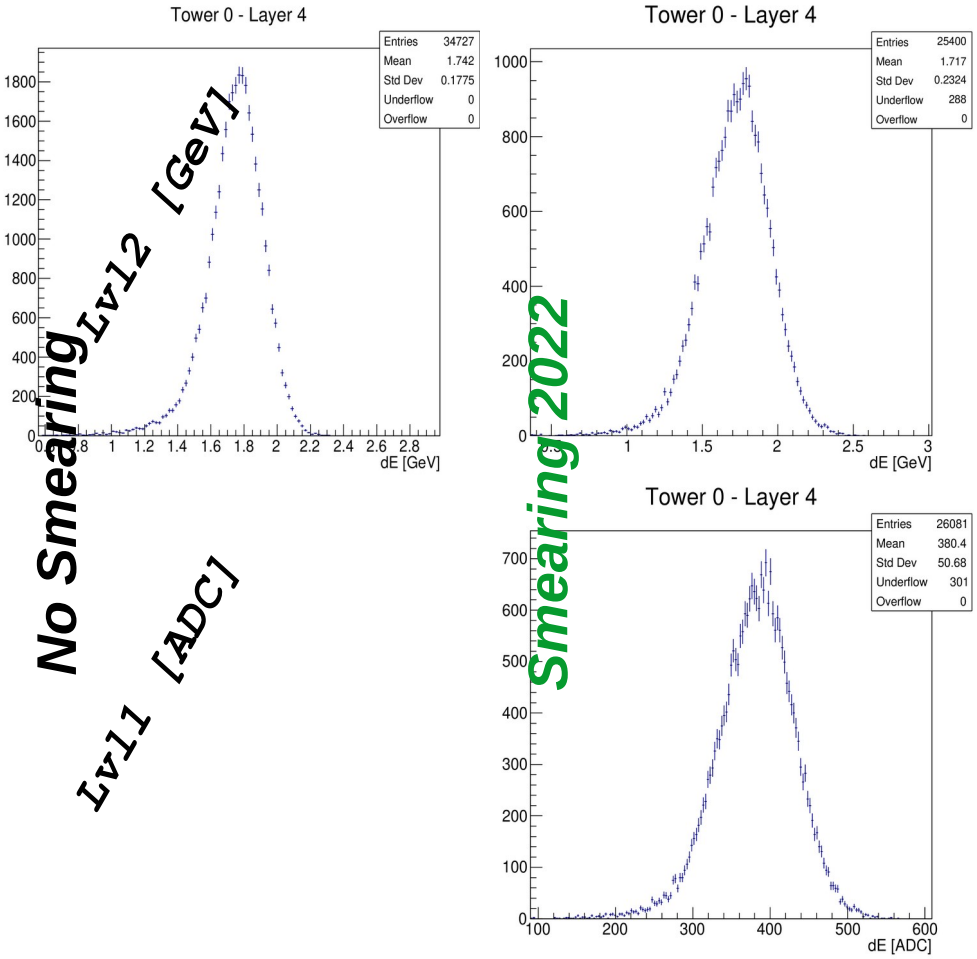








Cross check
using smearing 2022



LHC

$Gain_{LHC}$ [NRADC]
= G_{FACTOR} [600 V] x G_{HV} [600 → 400 V] x G_{CABLE}
= 3170 x 0.077 x 0.90 = **220 ADC/GeV**

$Noise_{LHC}$ [NRADC] = **34.286 ADC**

Δ_{RMS} (NoSmearing-Smearing2022)
$N = \sqrt{0.232^2 - 0.177^2} = 0.150$ GeV = 33 ADC

$Noise_{LHC}$ / Mean = **9.1%**

SPS

$Gain_{SPS}$ [NRADC] = **3170 ADC/GeV**

$Noise_{SPS}$ [NRADC] = **18.4 ADC**

$Noise_{SPS}$ / Mean = **0.3%**