Summary on the dead channel effect analysis

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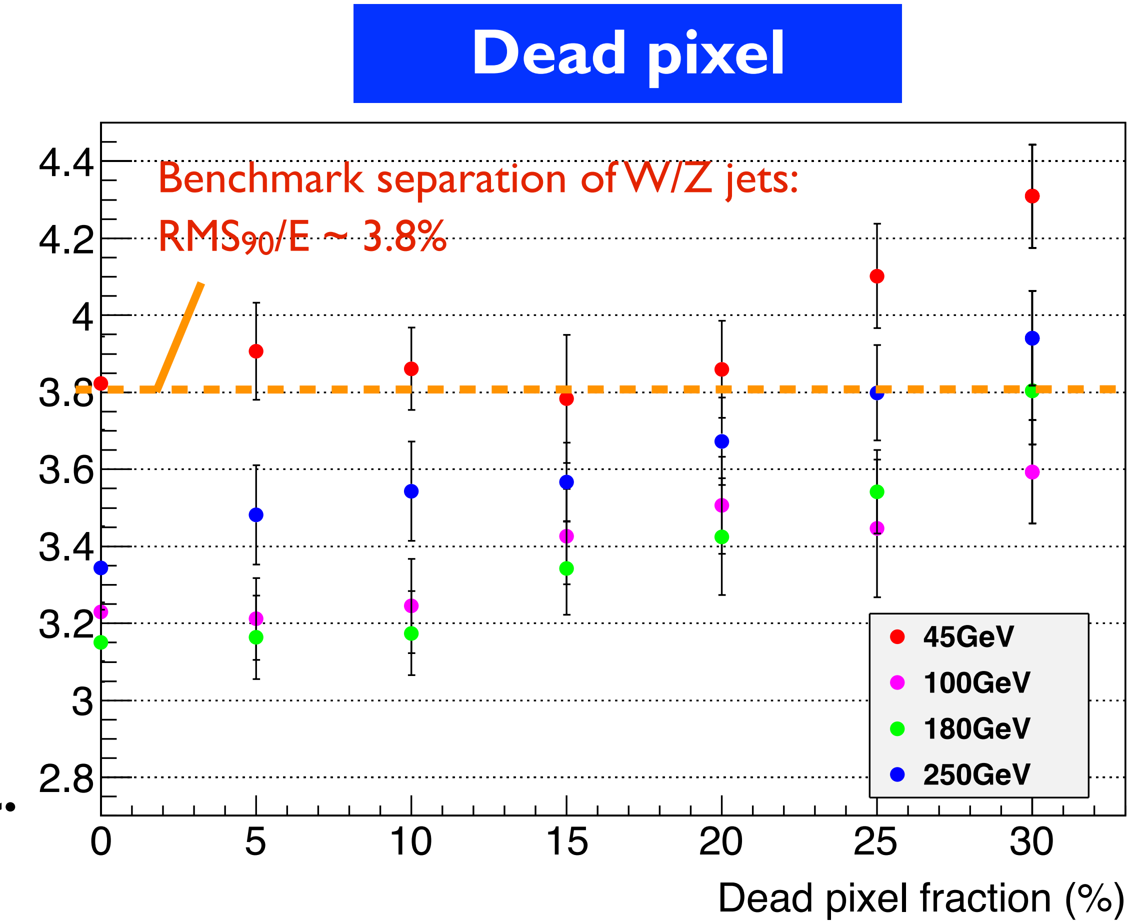
Calice Asia Meeting 7. Jun. 2013

Reminder

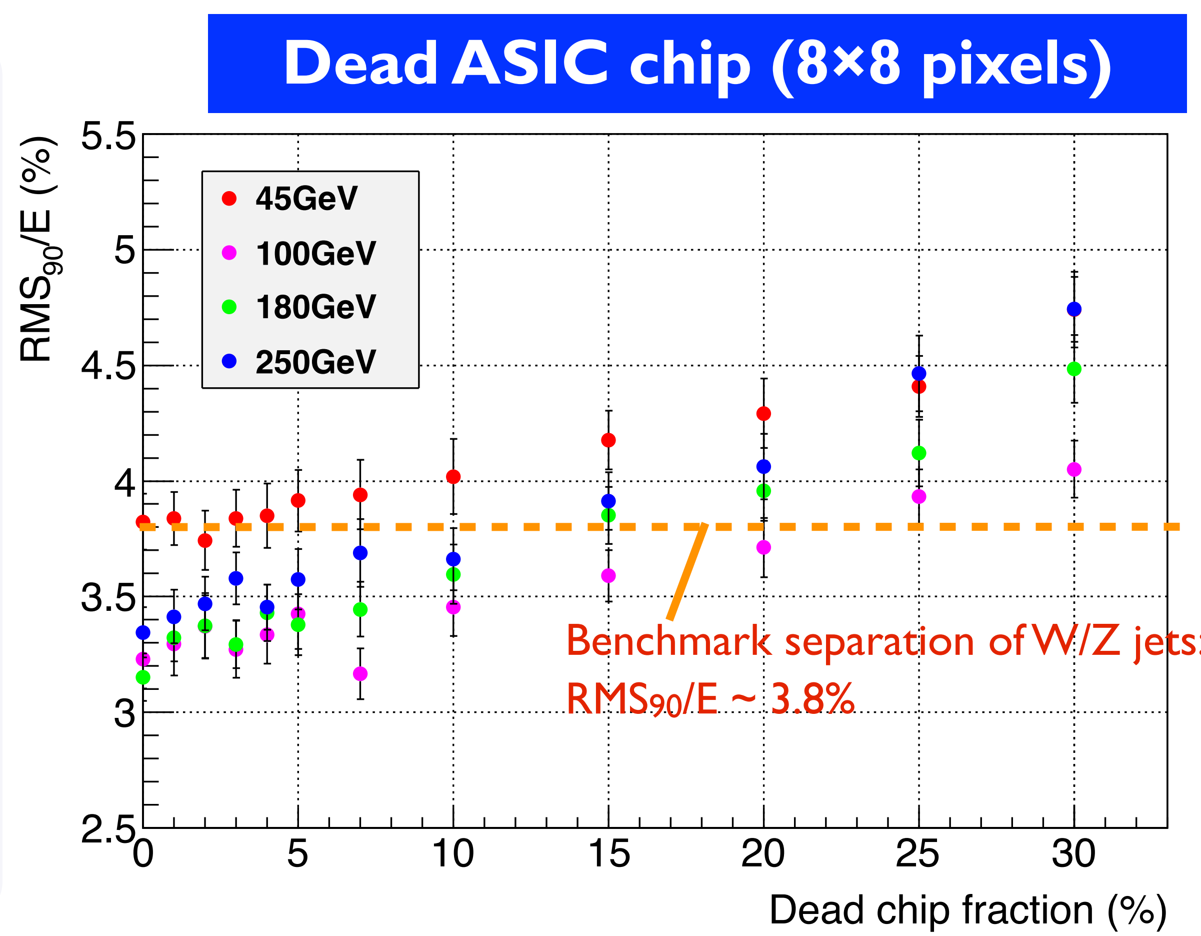
Jet Energy Resolution (JER) is not affected significantly with

~15% dead pixels
~5% dead chips

(Everybody has been funny to see this result. Actually I was not confident too.)



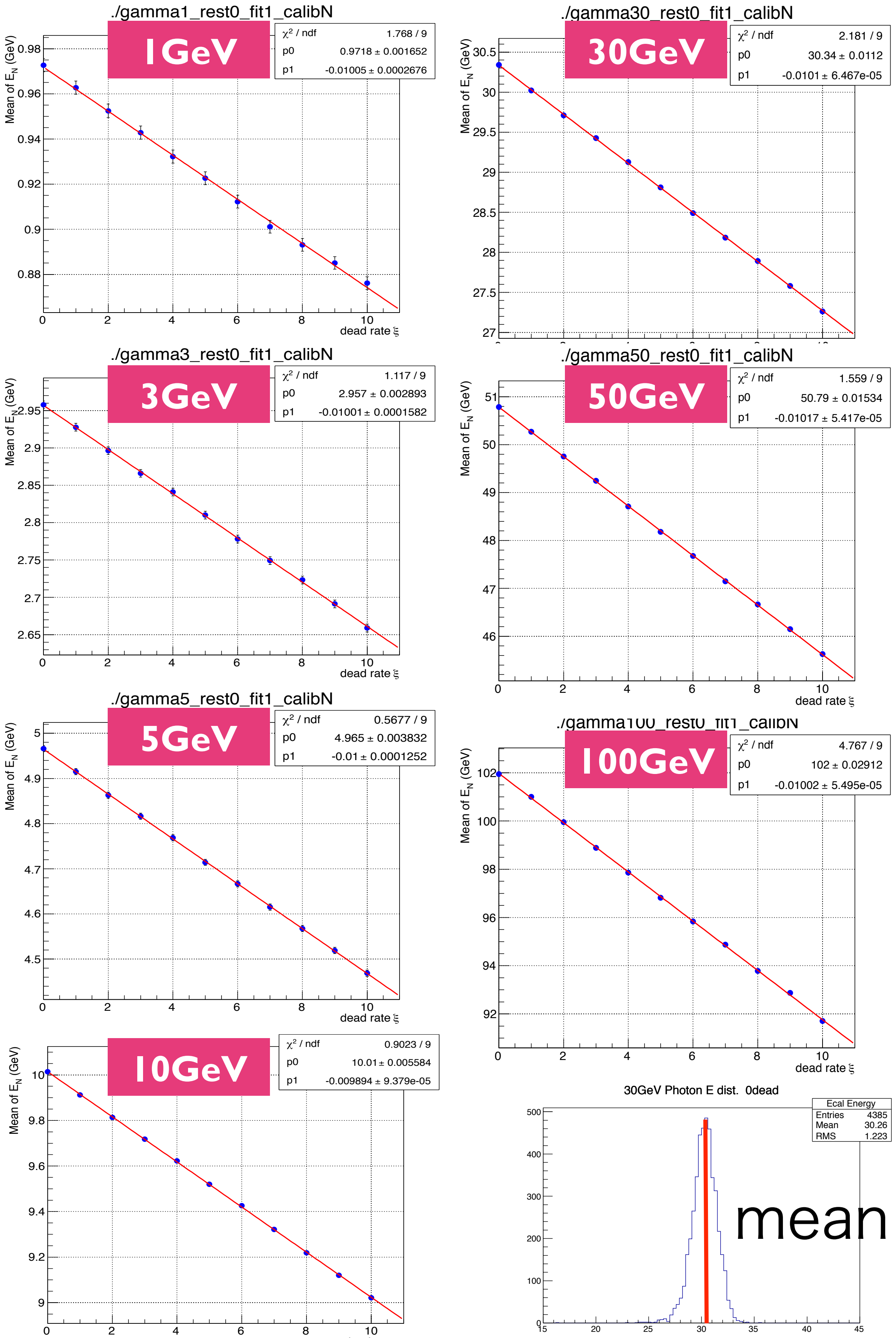
- **Miscellaneous checks**
  - Mean of energy distribution
  - Mean of hit number



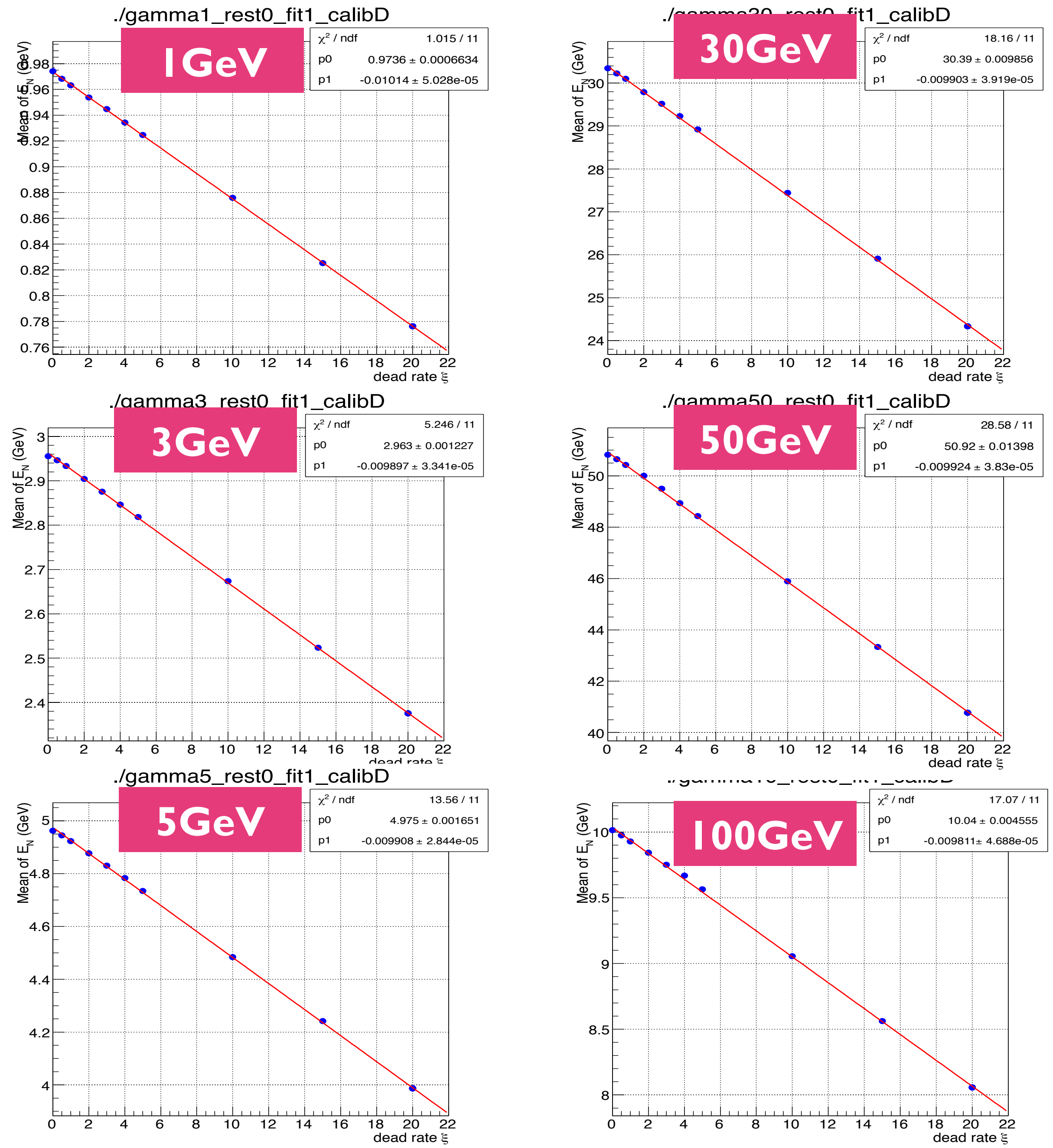
Mean of energy (Single photon event)

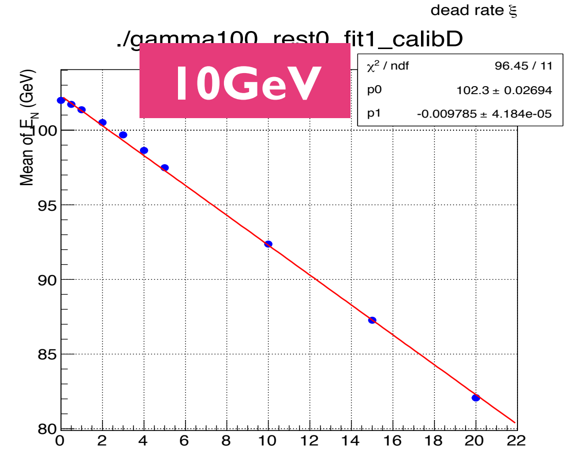
The drop rate = dead fraction

(Dead pixels)



(Dead chips)



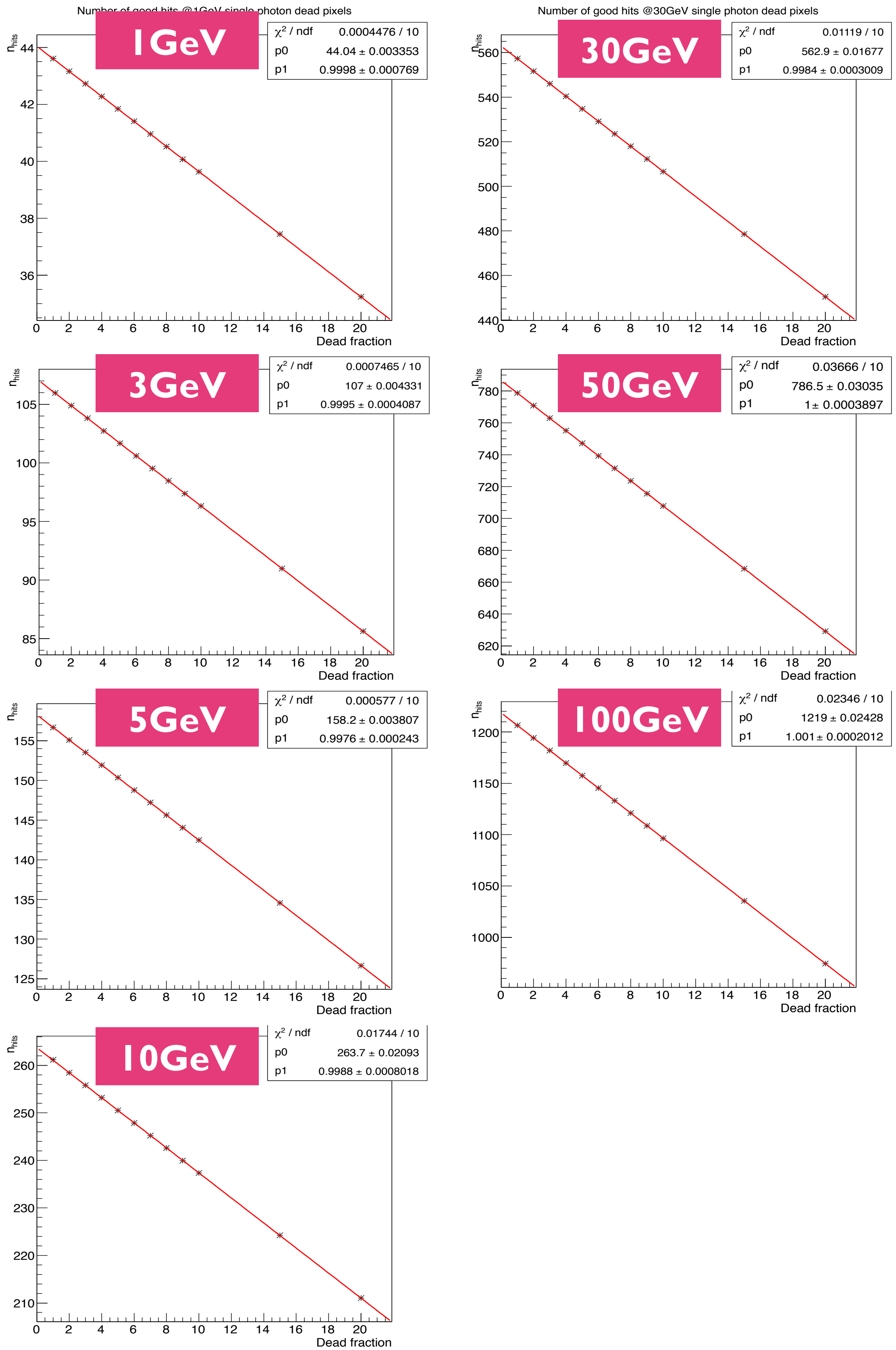


(fit) $E = p_0(1 + p_1\xi)$

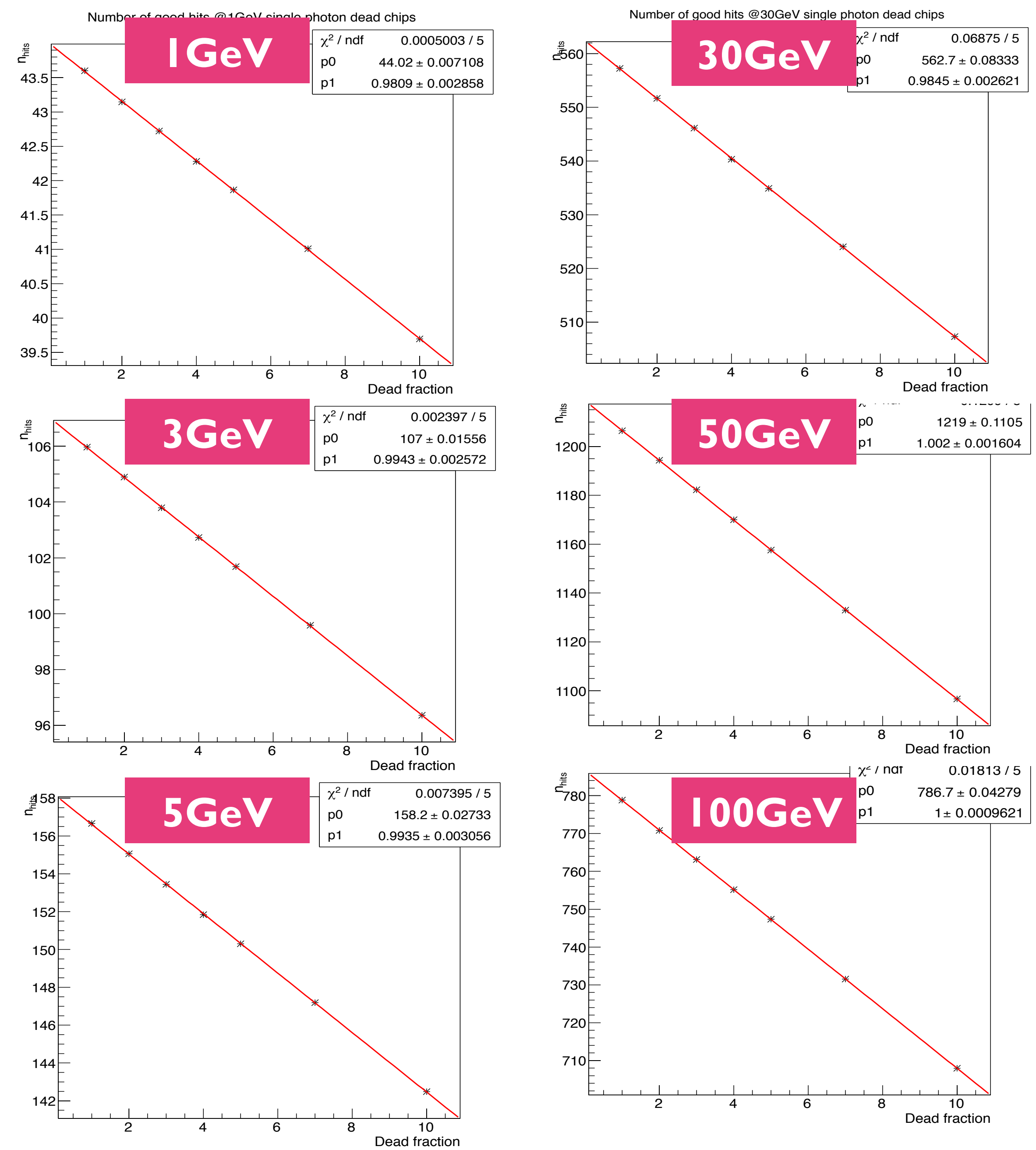
Mean of number of hits in a qqbar 2 jet event

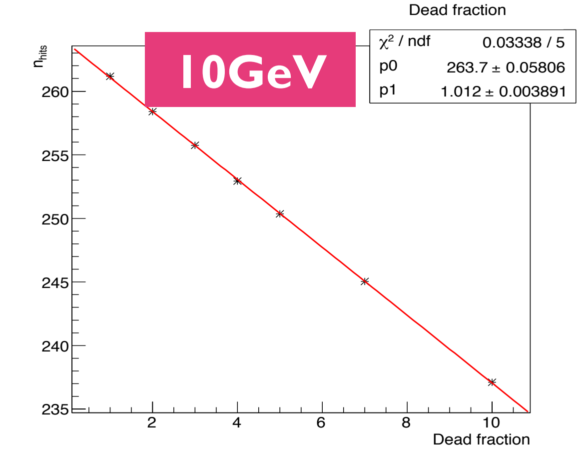
The drop rate = dead fraction

(Dead pixels)



(Dead chips)





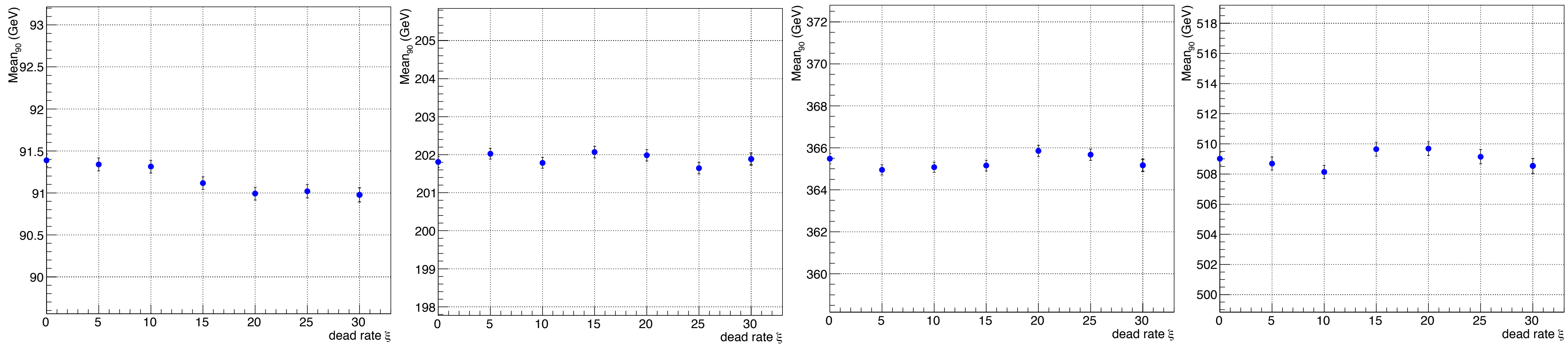
(fit) $E = p_0(1 + p_1\xi)$

Mean of energy (qqbar 2jets event)

After re-calibration C→C/(1-ξ)
(in order to match the calibration to TPC and HCAL)

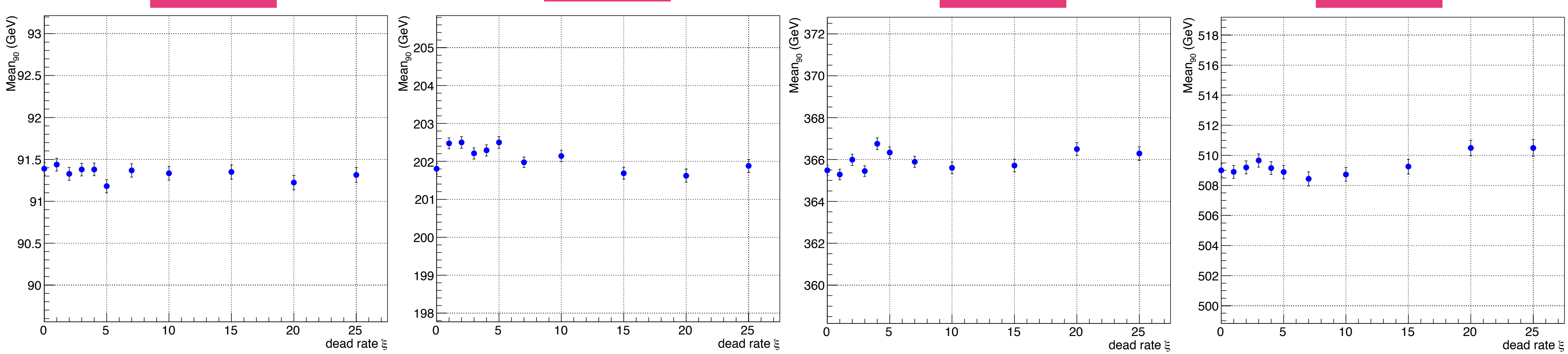
(Dead pixels)

91GeV | 200GeV | 360GeV | 500GeV



(Dead chips)

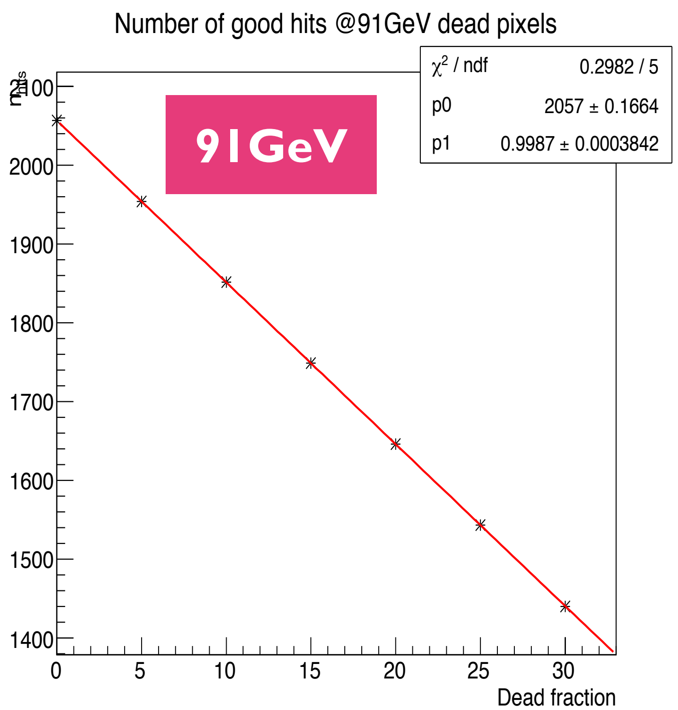
91GeV | 200GeV | 360GeV | 500GeV

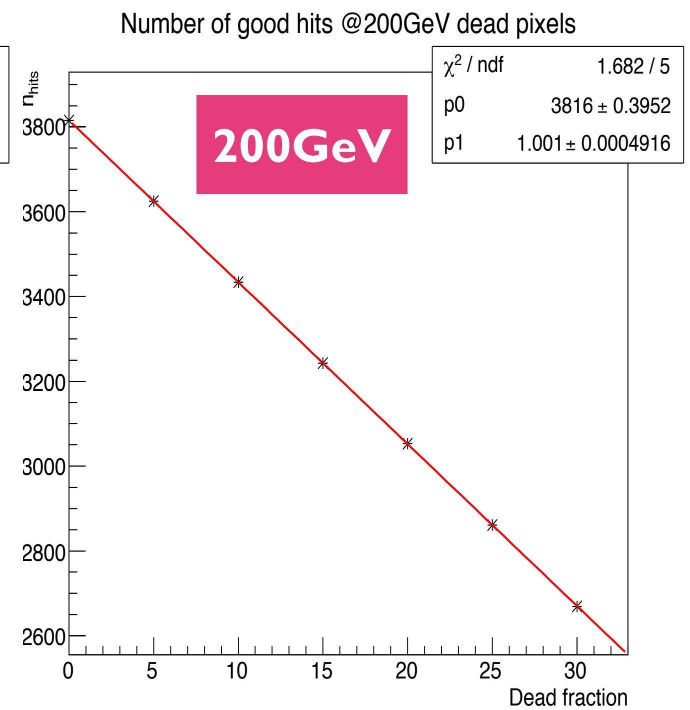


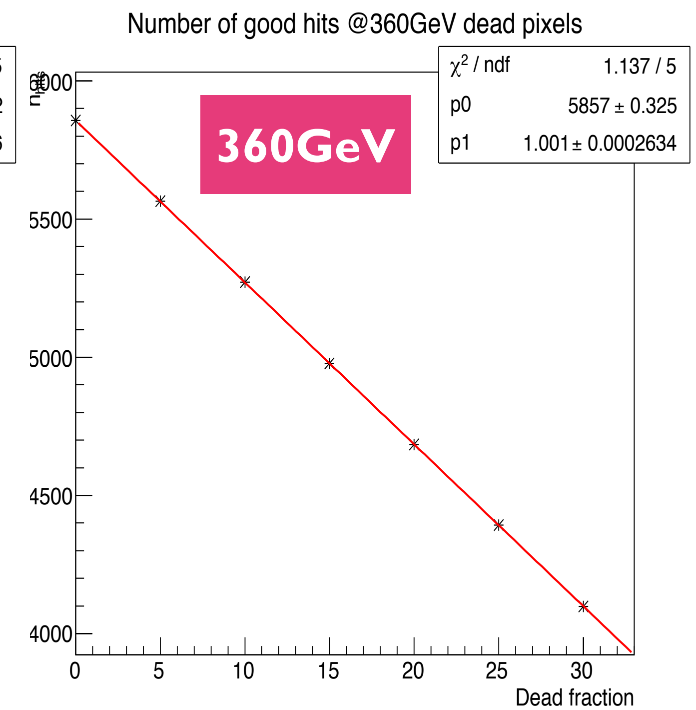
Mean of number of hits in a qqbar 2 jet event

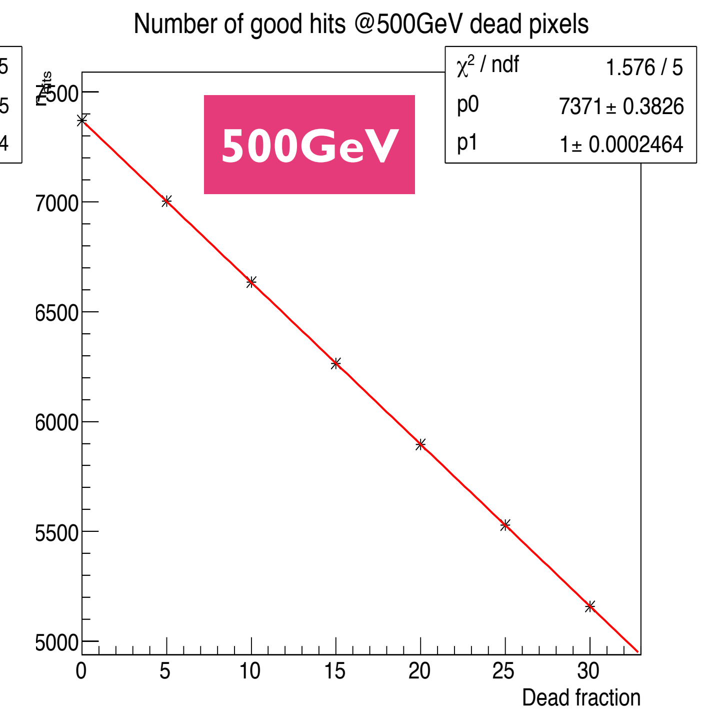
The drop rate = dead fraction

(Dead pixels)

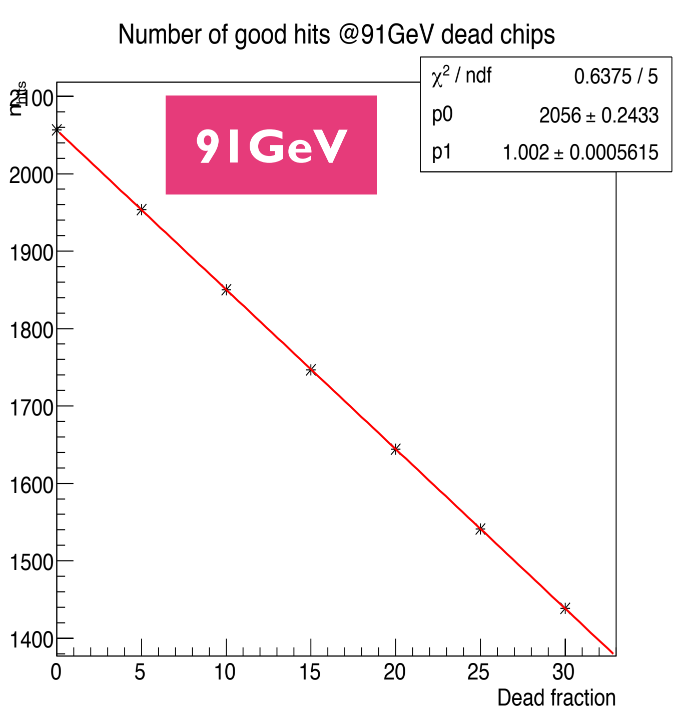




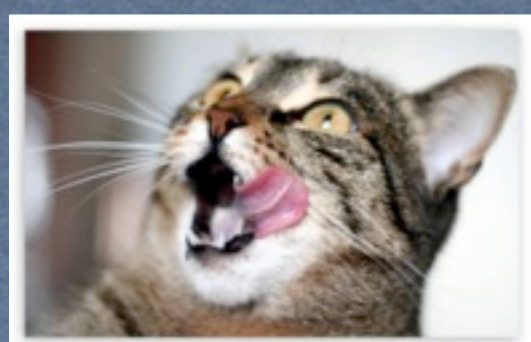


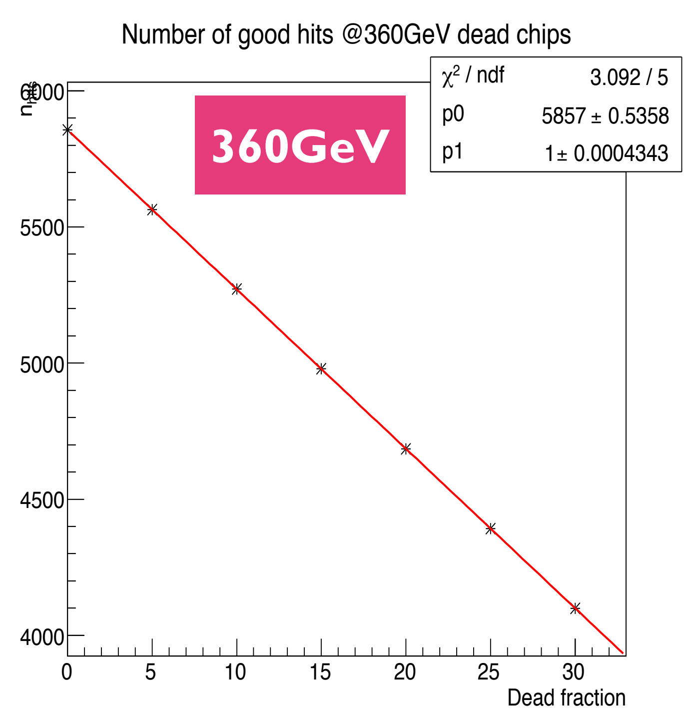


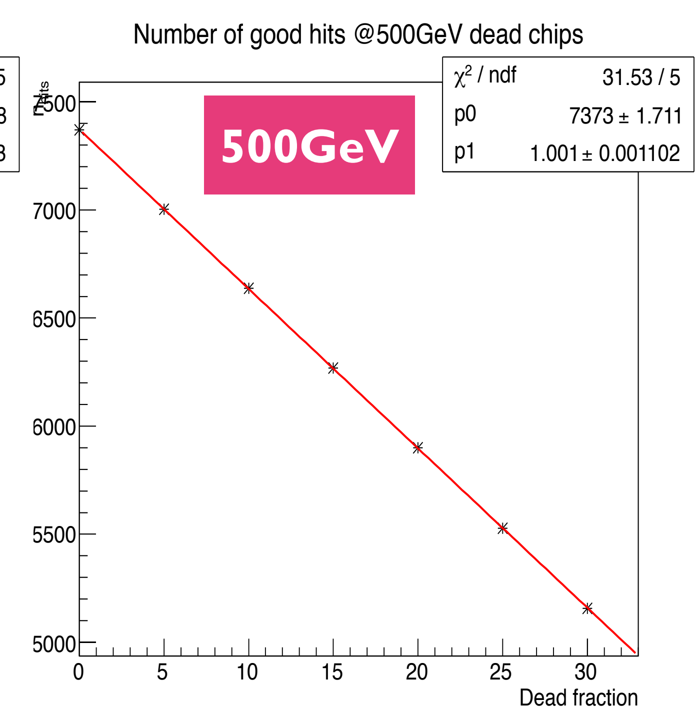
(Dead chips)



The file of 200GeV/chip was lost...







(fit) $E = p_0(1 + p_1 \xi)$

Reminder

Jet Energy Resolution (JER) is not affected significantly with

~15% dead pixels
~5% dead chips

(Everybody has been funny to see this result. Actually I was not confident too.)

- **Miscellaneous checks**

  Mean of energy distribution

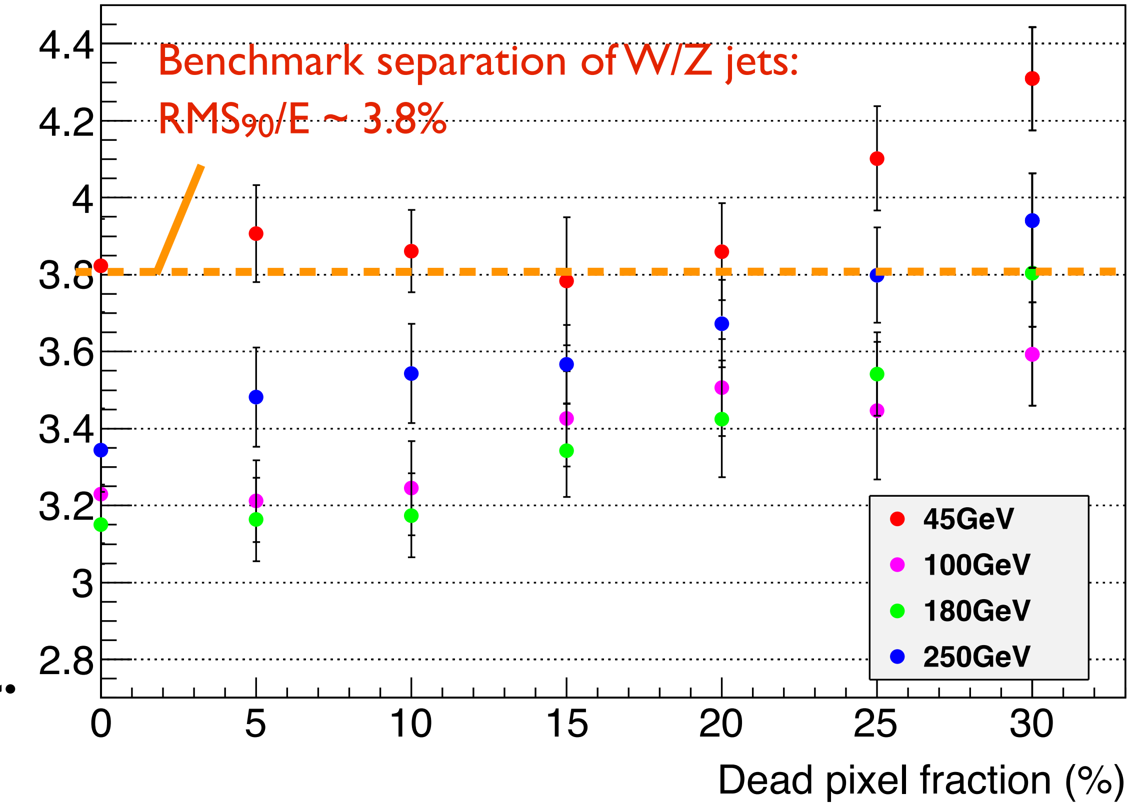
  Mean of hit number

  --- drop linearly as expected

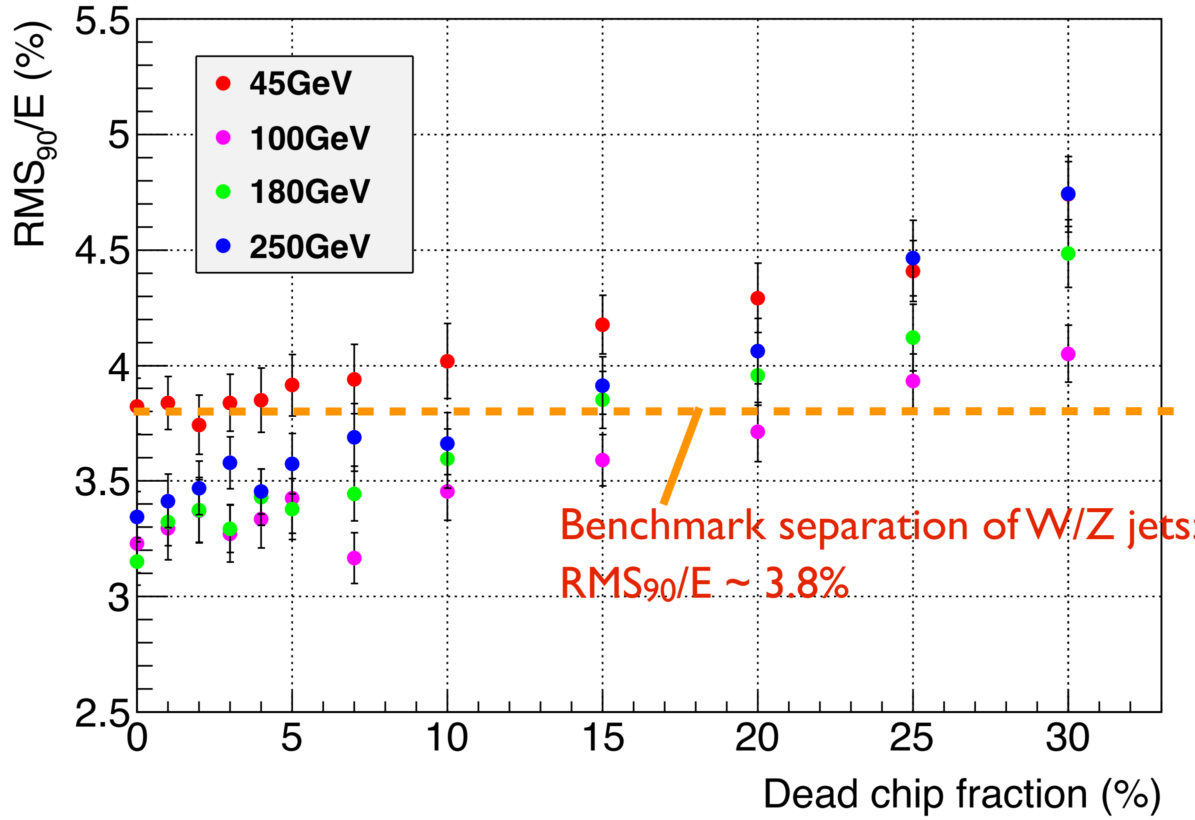
  Comparison between event-by-event selecting configuration and fixed one

  --- no difference

Dead pixel

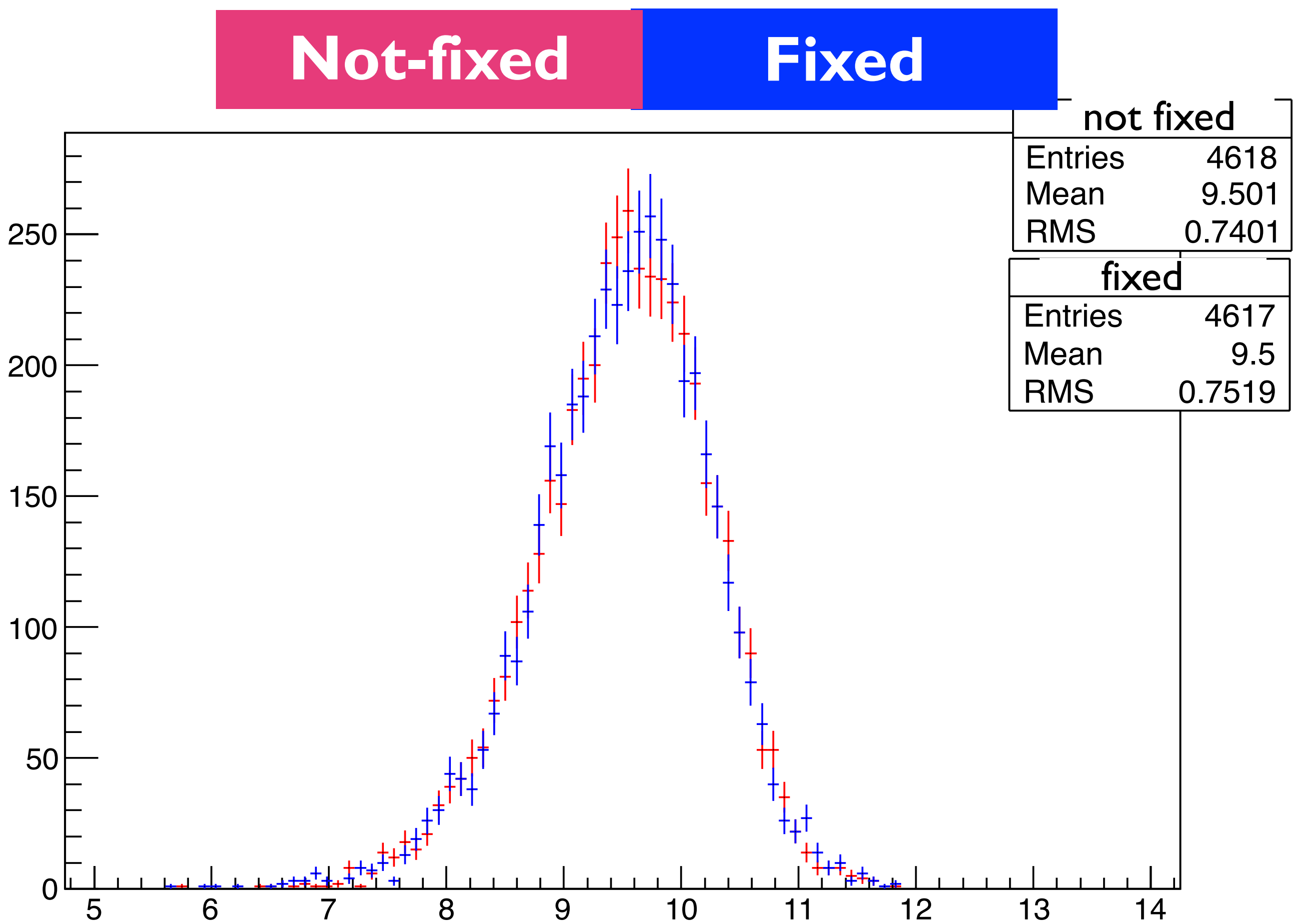


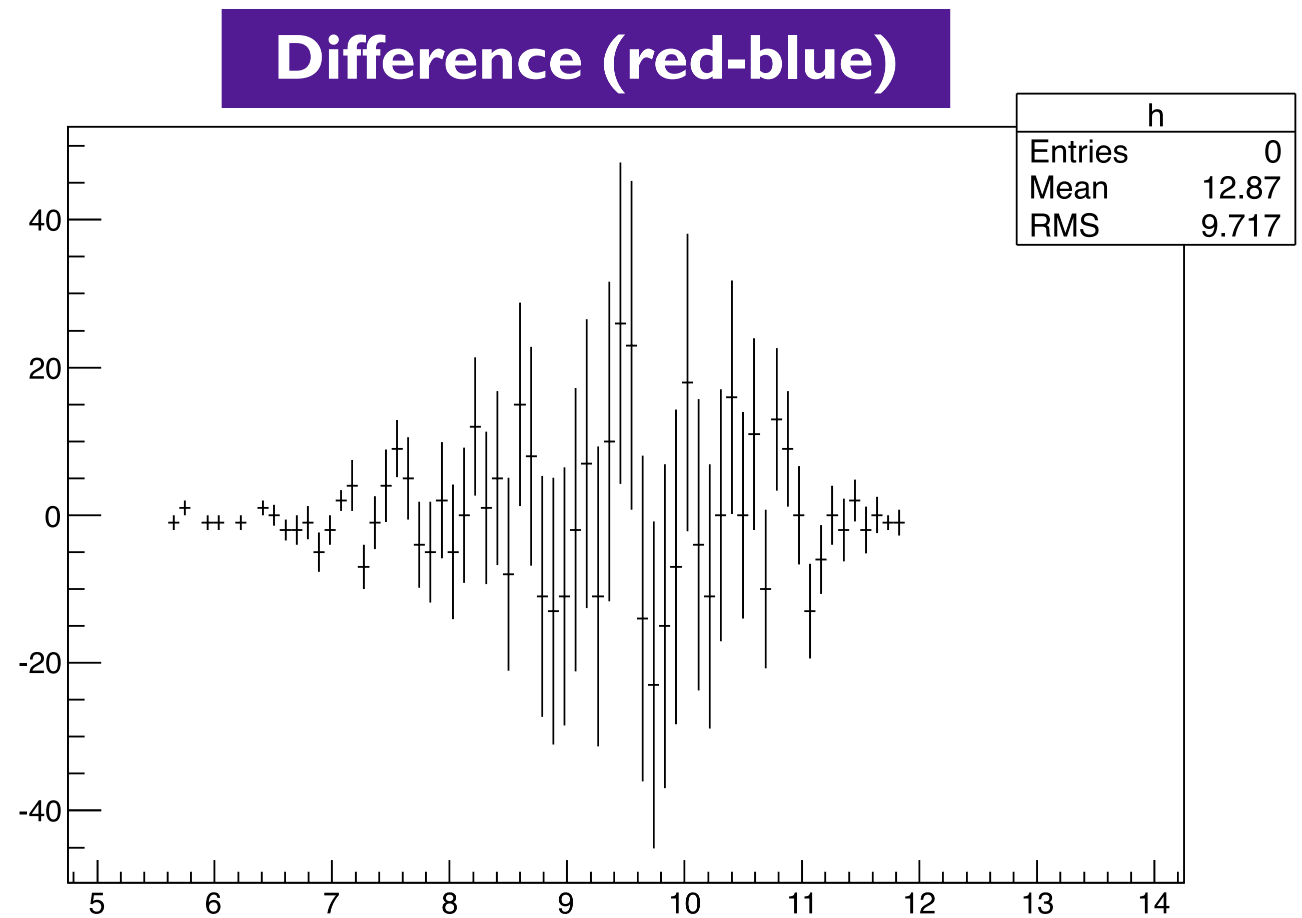
Dead ASIC chip (8×8 pixels)



Event-by-event choice vs Fixed configuration

e.g. Energy distribution of 10GeV Single photon evt w/ 5% of dead chips





Consistent with statistic fluctuation

Other E, Dead fraction: Same

Reminder

Jet Energy Resolution (JER) is not affected significantly with

~15% dead pixels
~5% dead chips

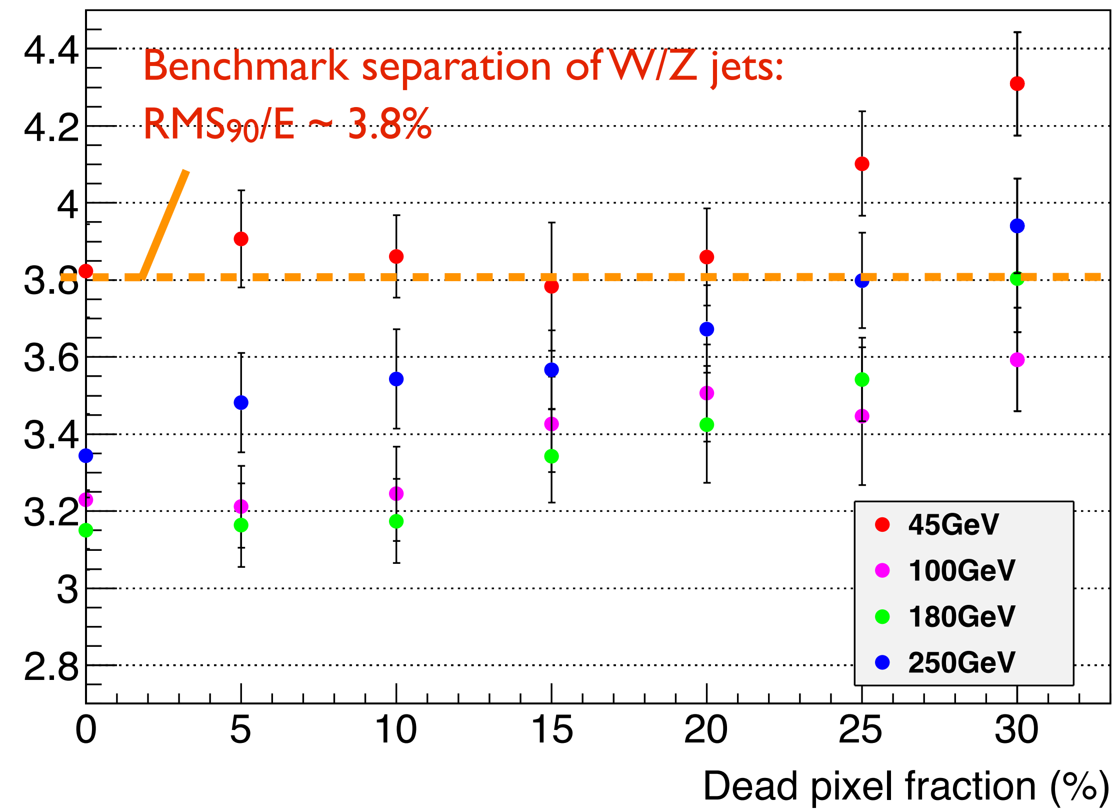
▪Simulation seems to work appropriately

Why 15% of dead pixels are ok?

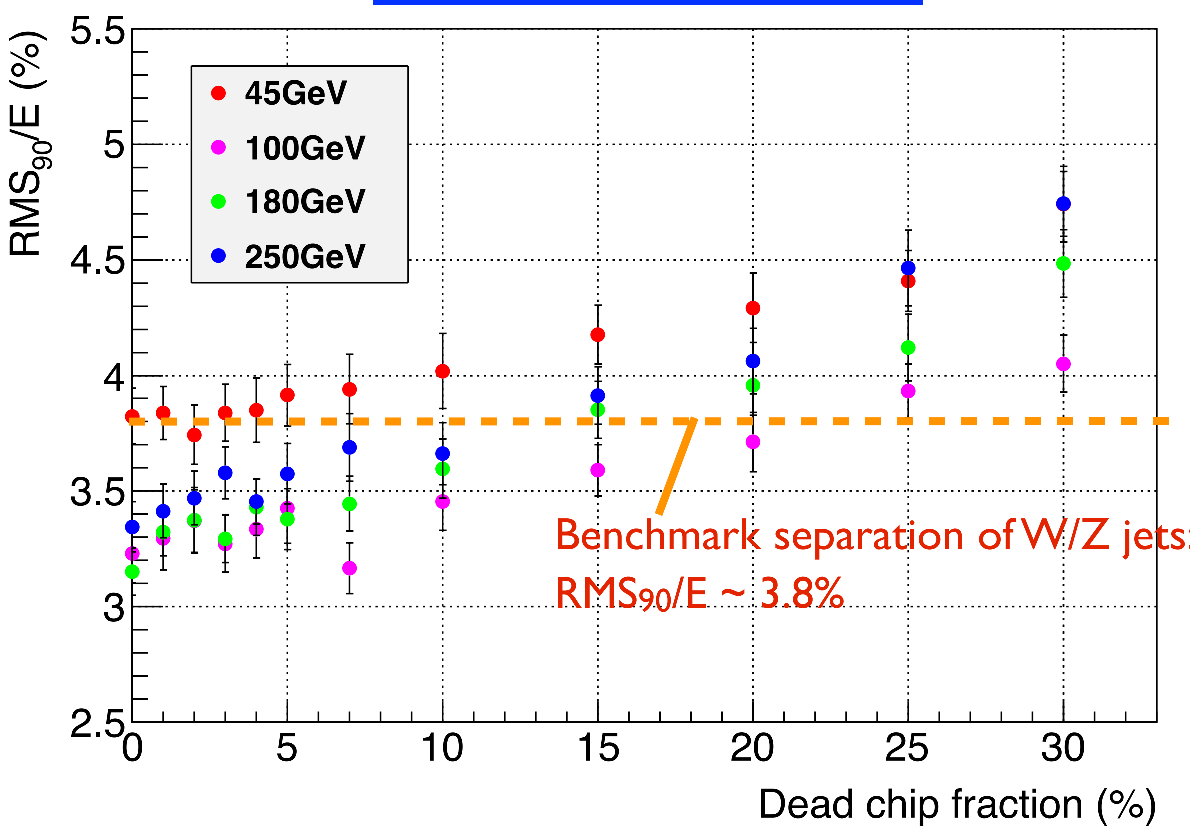
Study

- Quantitate analysis of dead channel effect to ECAL resolution
- Discuss dead channel impact on JER with the result of above

Dead pixel



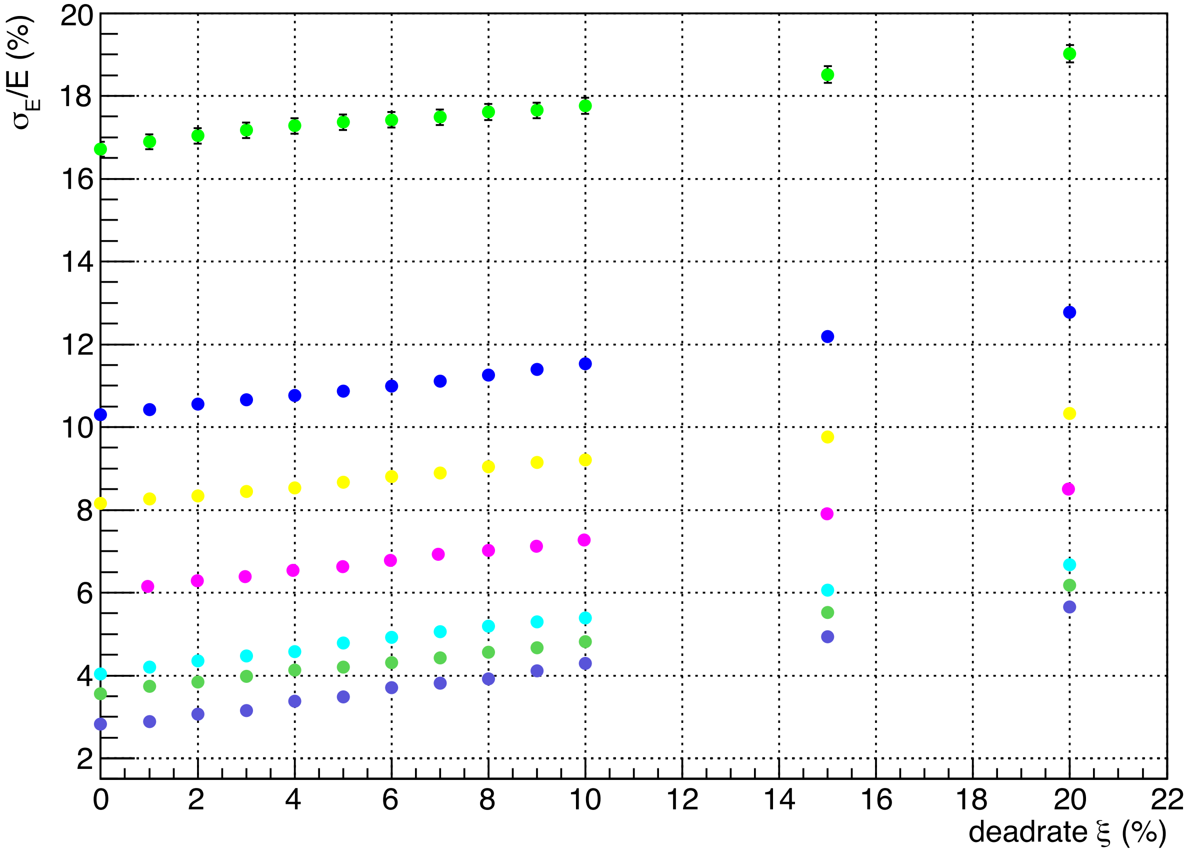
Dead chip



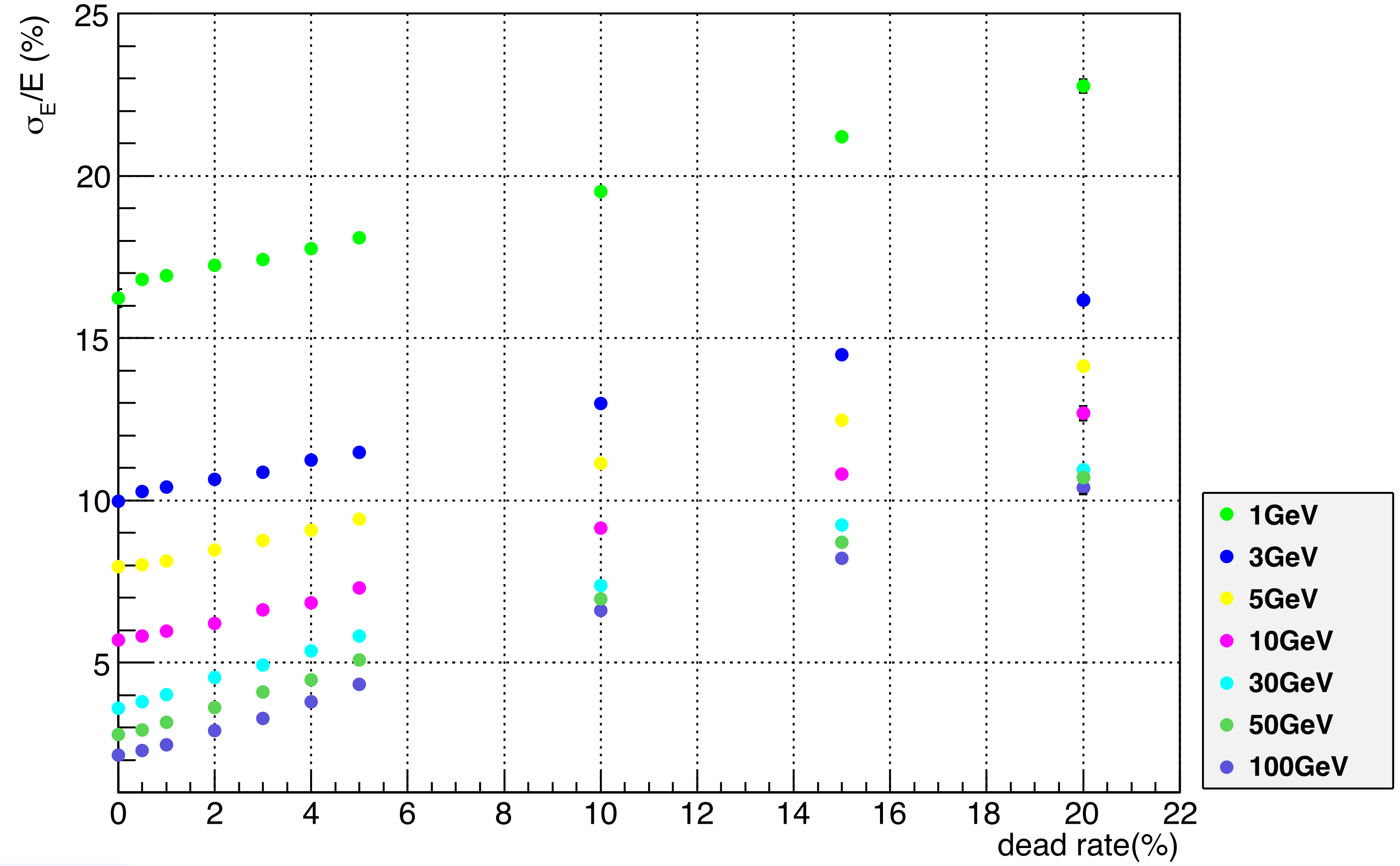
Dead channels effect to ECAL resolution

Evaluate ECAL performance by energy resolution of single photon events

Dead pixel



Dead chip



Single particle energy resolution:

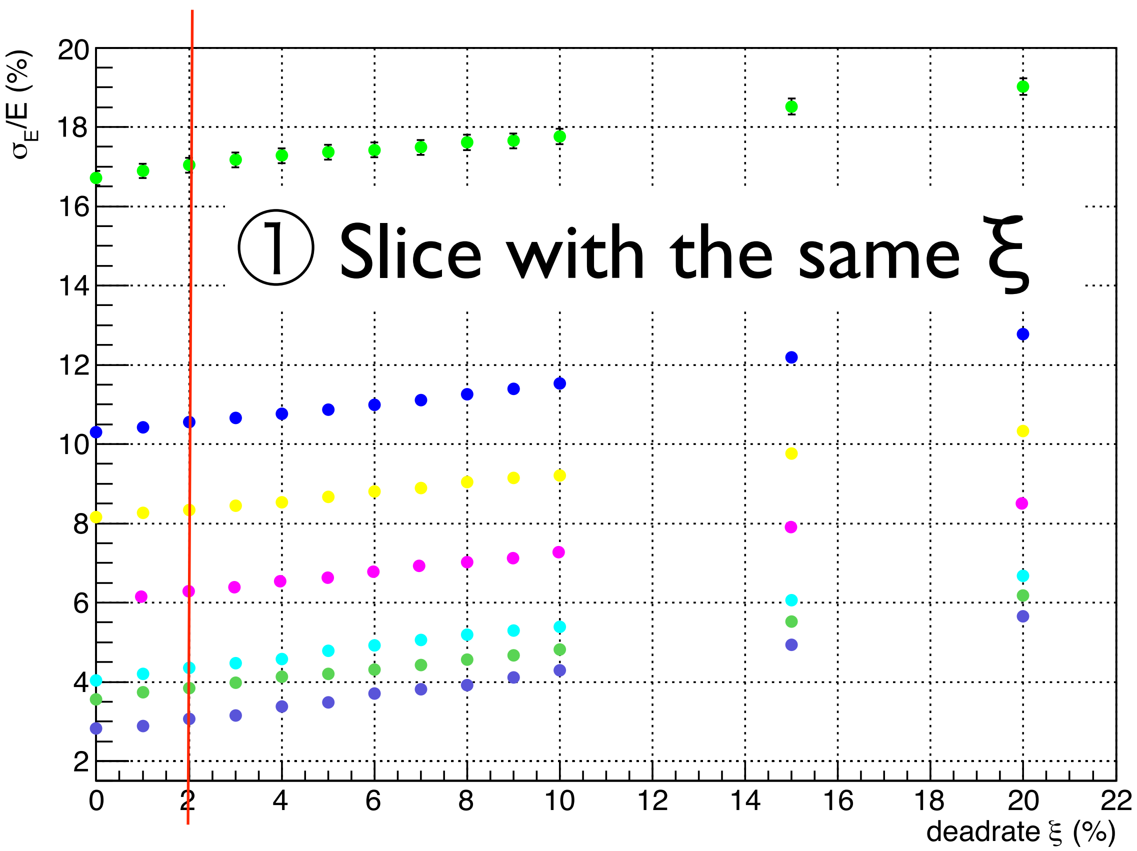
Const. — Stochastic — Noise

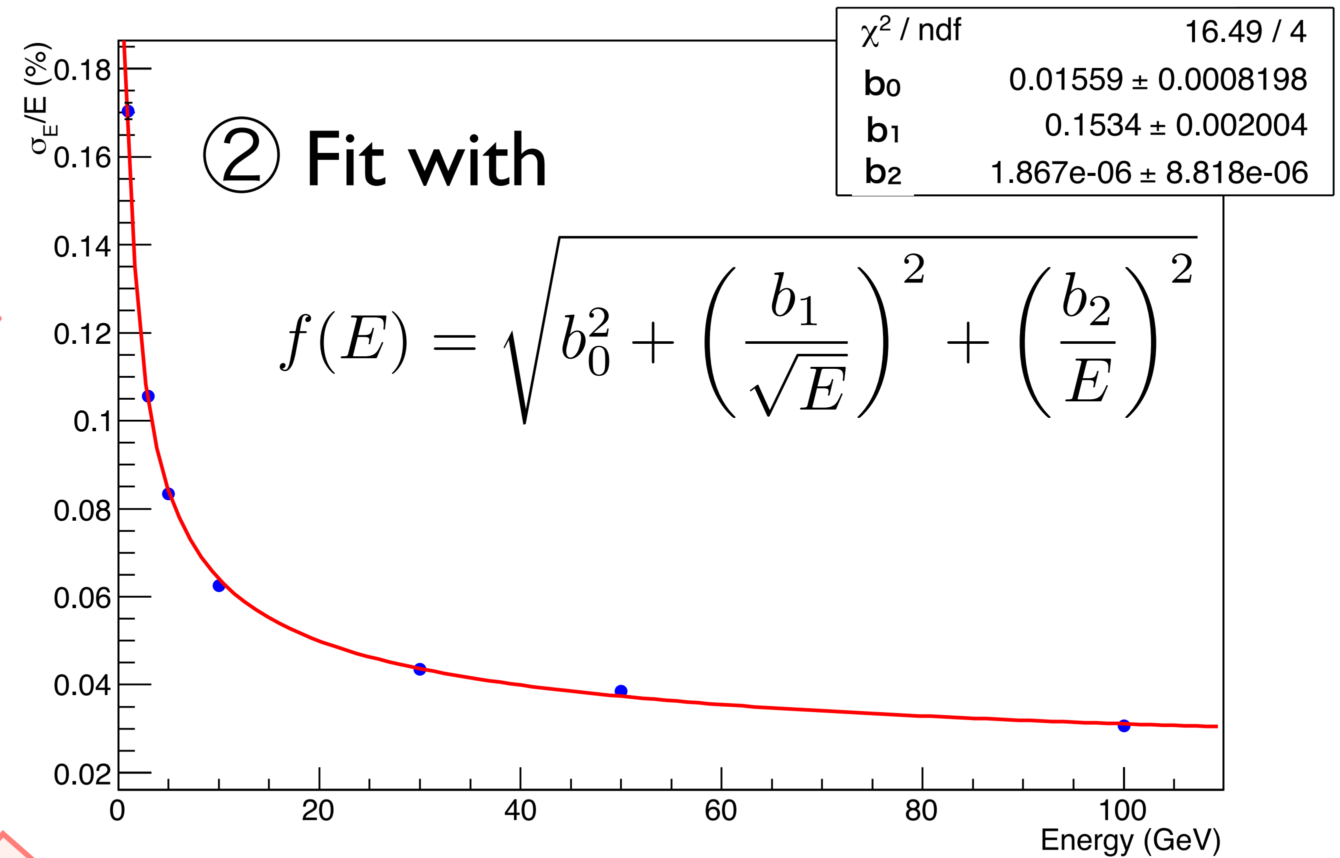
$$\frac{\sigma_E}{E} = b_0(\xi) \oplus \frac{b_1(\xi)}{\sqrt{E}} \oplus \frac{b_2(\xi)}{E}$$

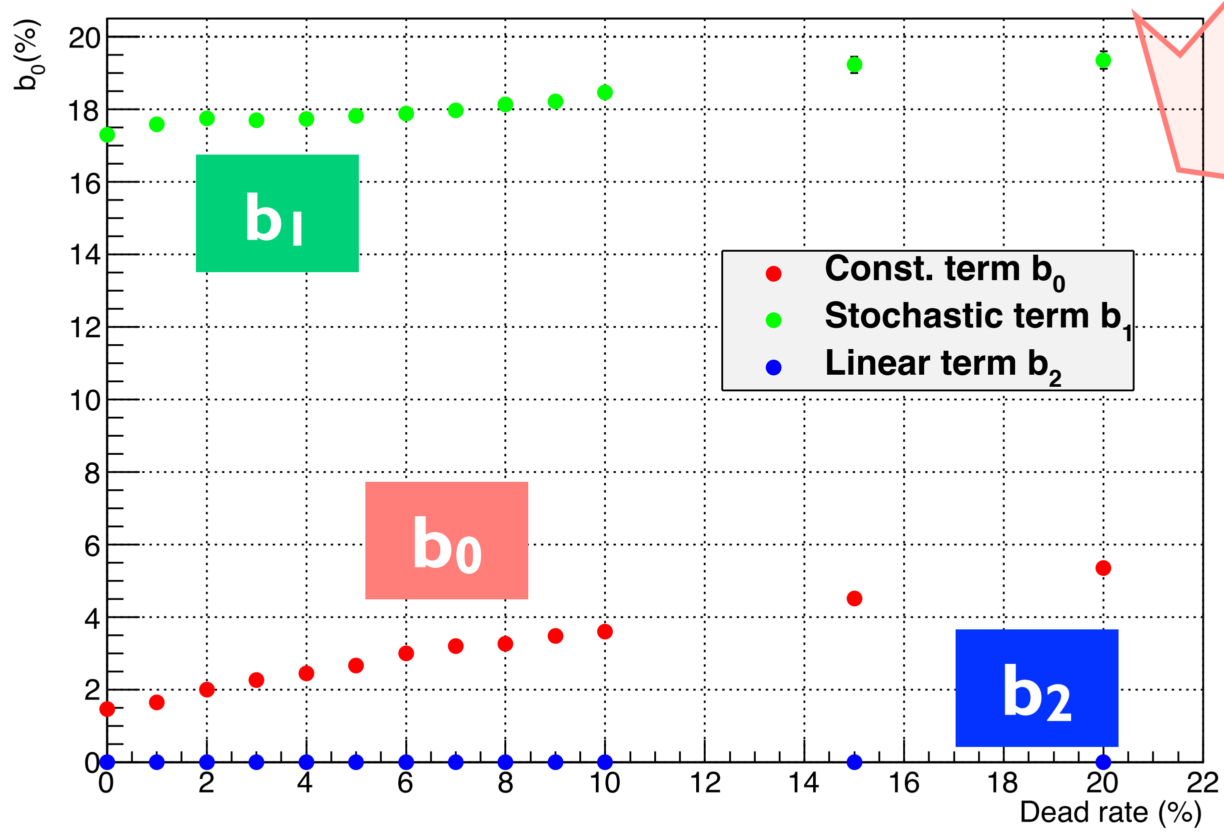
Photons with higher energy experience more degrade

Dead channel effect can be reduced to b_0, b_1 ,b_2 dependences on ξ

ξ dependence of b_0, b_1, b_2







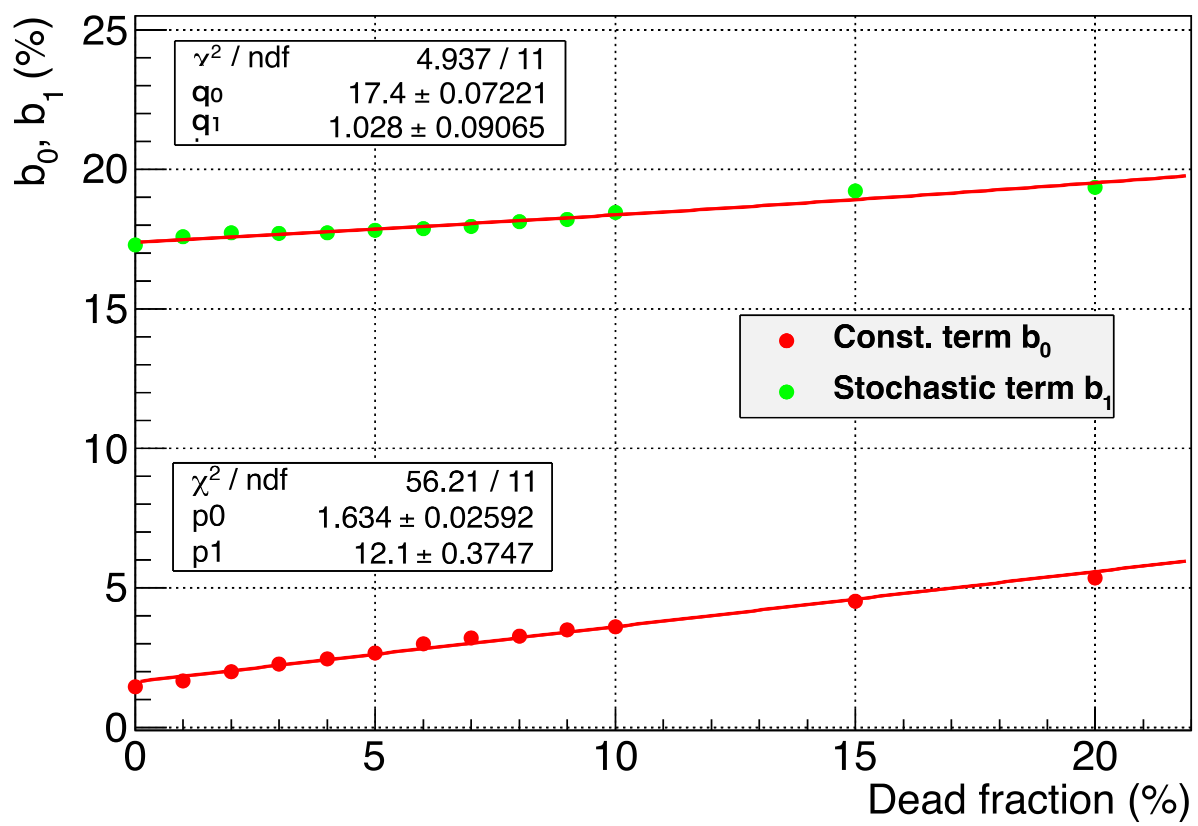
③ Plot b_0, b_1, b_2 for every ξ

(b_2 is always ~0 ⇒ Fix b_2 =0)

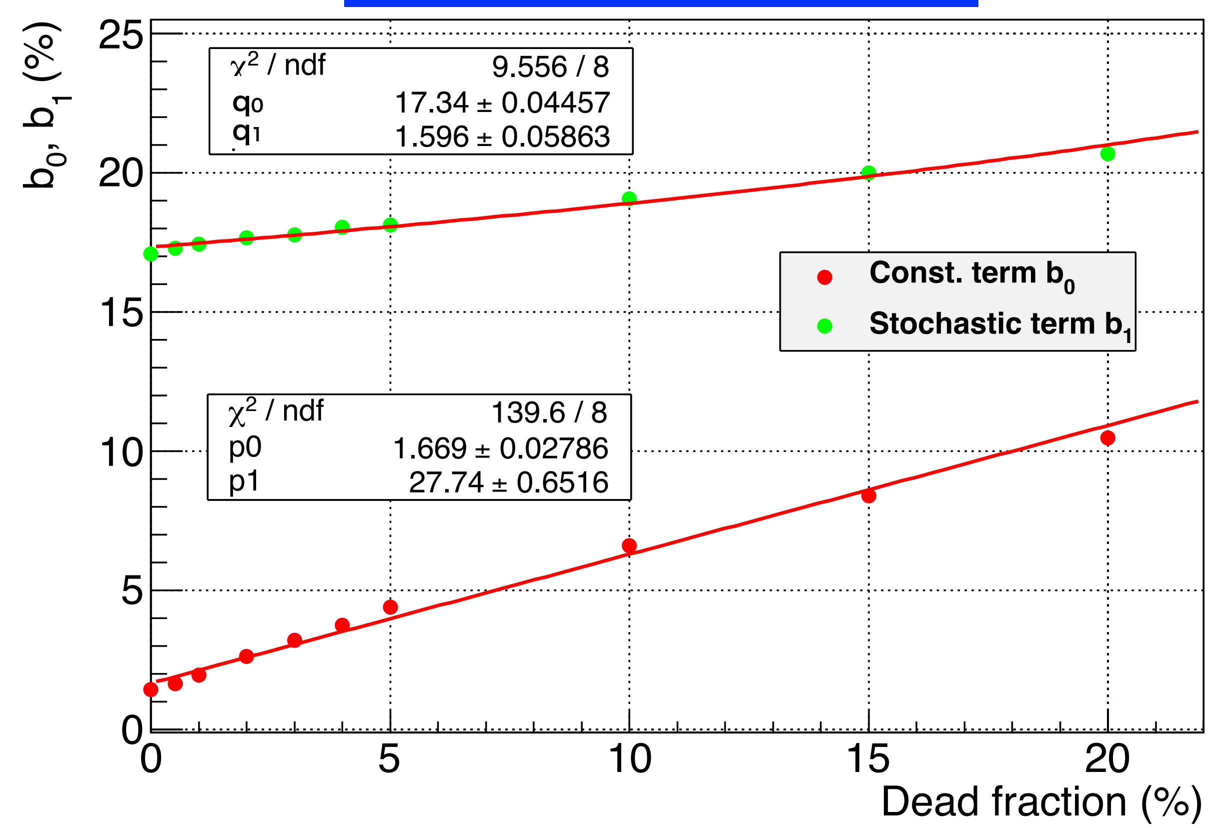
ξ dependence of b_0, b_1

$$\frac{\sigma_E}{E} = b_0(\xi) \bigoplus \frac{b_1(\xi)}{\sqrt{E}}$$

Dead Pixel



Dead Chip



- Dead channels mainly affect constant term
- Low energy → stoch. (b_1) is dominant
  → small effect by dead channels

  High energy → const. (b_0) isn't negligible → large effect
- Parametrize as $b_0(\xi) = p_0\,(1 + p_1\,\xi)$ & $b_1(\xi) = \dfrac{q_0}{\sqrt{1 - q_1\,\xi}}$

(Fit parameters)

	Pixel	Chip
p_0	1.6	
p_1	12	28
q_0	17.4	
q_1	1.0	1.6

How does dead channels make stoch. term worse ?

--- The effective sampling fraction change

- **Shower energy:** ("~": the average of LHS/RHS match)

$E \sim E_{MIP} \times n_{MIP}$, $\sigma_E/E \propto 1/\mathrm{sqrt}(n_{MIP}) \propto 1/\mathrm{sqrt}(E)$ (Poisson statistics)

"stochastic"

- **Measured energy in a sampling calorimeter**

$E \sim E_{MIP} \times n_{MIP} \sim E_{MIP} \times n_{MIP,S} \times 1/C_S$

sampling ratio ($1/C_S$)

Number of MIP signals in sensor area ($n_{MIP,S}$)

$\sigma_E/E \propto 1/\mathrm{sqrt}(n_{MIP,S}) \propto 1/\mathrm{sqrt}(E C_S)$

- **When with a fraction of ξ dead channels in sensor area**

$n_{MIP,S} \rightarrow (1-\xi)\, n_{MIP,S}$

Sampling ratio changes accordingly: $C_S \rightarrow (1-\xi)\, C_S$

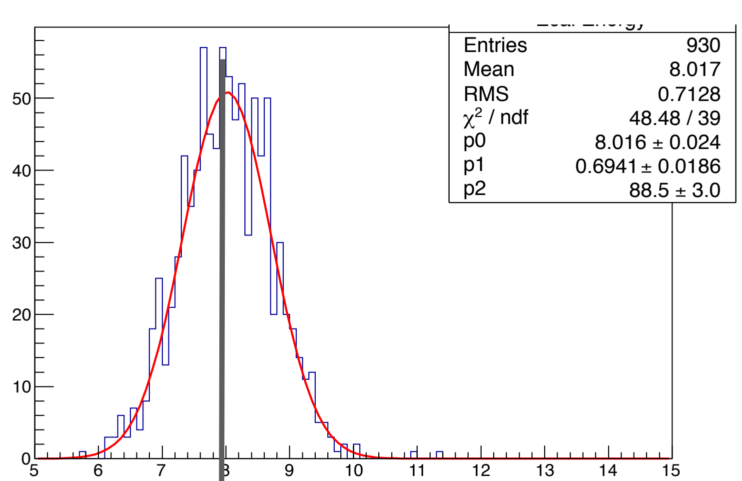
$\sigma_{Em}/E \propto 1/\mathrm{sqrt}(E(1-\xi)C_S) \rightarrow b_1 \propto 1/\mathrm{sqrt}(1-\xi)$

$$b_1(\xi) = \frac{q_0}{\sqrt{1 - q_1\, \xi}}$$

$q_1 = 1$ if no other contribution to $1/\sqrt{E}$ term

How does dead channels make const. term worse ?

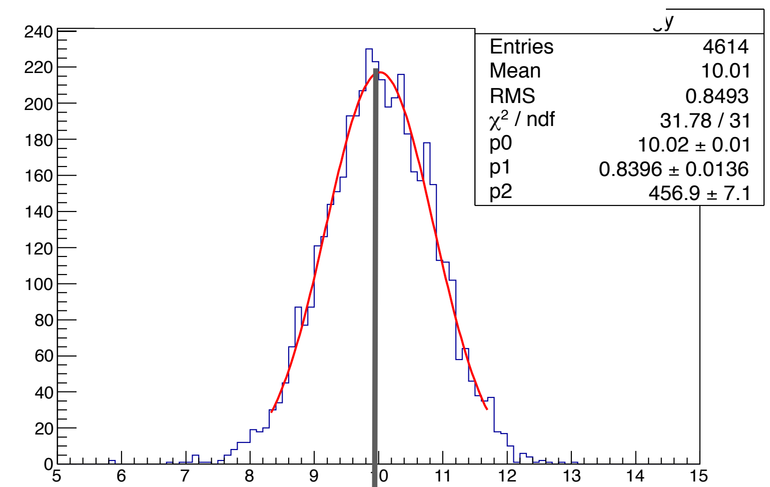
The calibration coefficient C is scaled to C/1-ξ, according to the sampling ration change Cs → Cs(1-ξ)   (So that mean energy remains in the correct position)



$E_0(1-\xi)$

C → C/(1-ξ)

re-calibrate



E_0

Uniformly distributed dead channels are assumed. (ξ: average dead channel fraction)

But! the fraction in a single shower fluctuates statistically

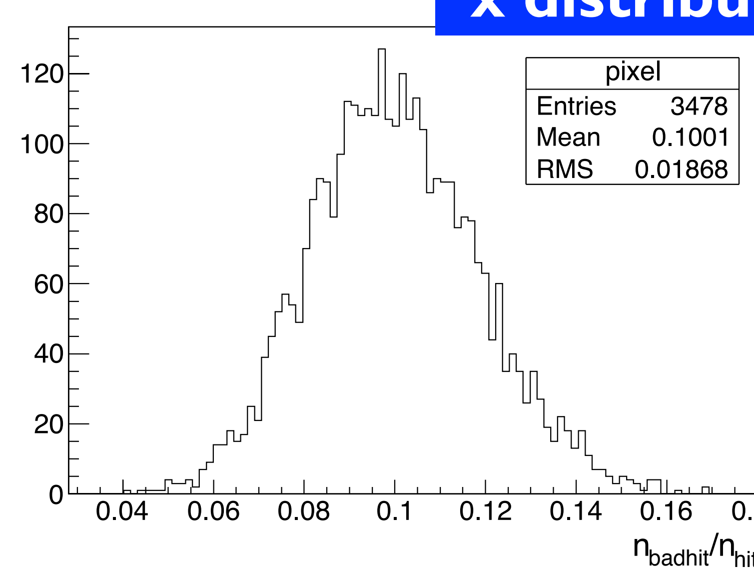
Binomial distribution: $P(n) = {}_NC_n\, \xi^n (1-\xi)^{N-n}$ (N: #hits, n: #bad hits)

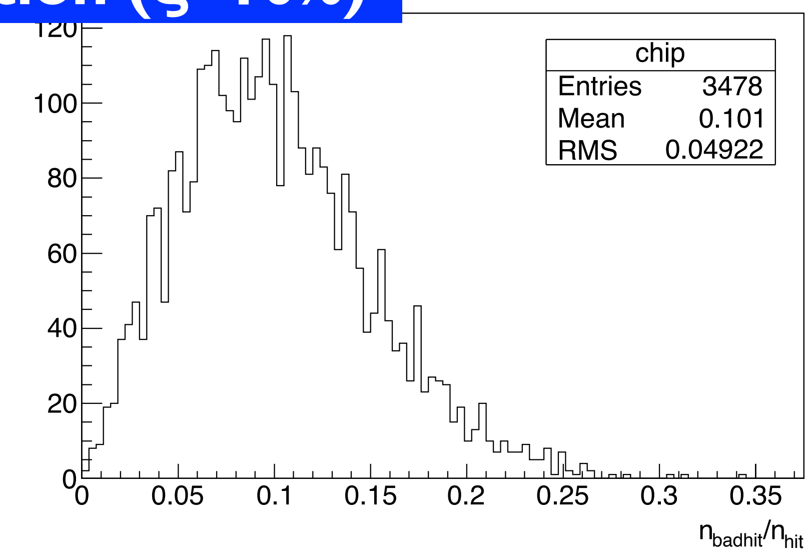
x := n/N

The mean position is not recovered correctly if x != ξ

(Dead chips give the larger dispersion)

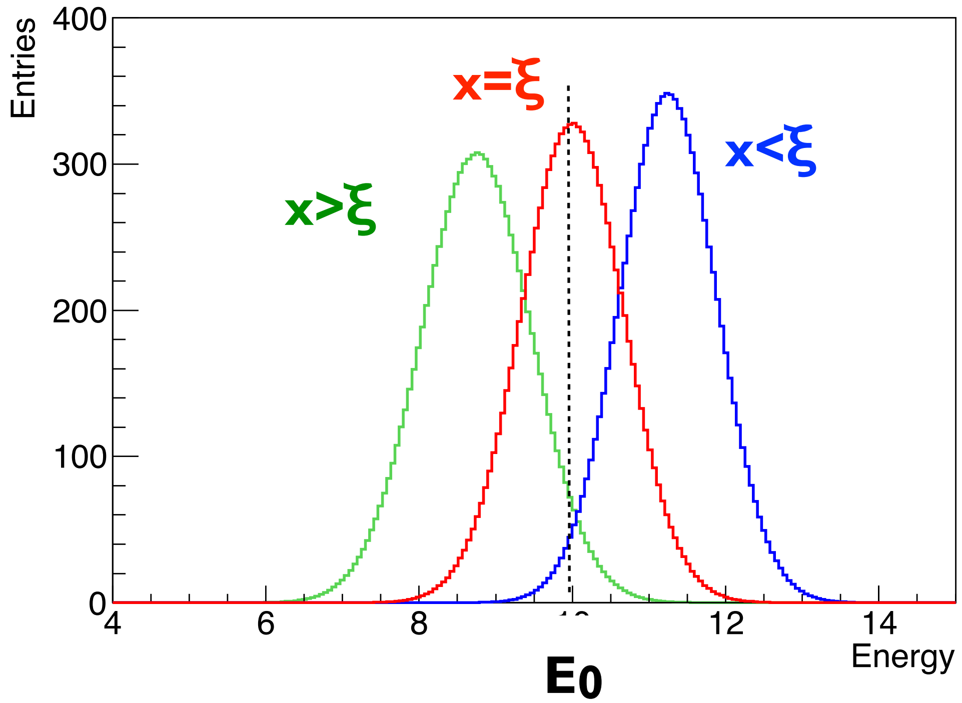
x distribution (ξ=10%)





How does dead channels make const. term worse ?

- Energy distribution ends up in the superposition of many gaussians with different mean positions. → Broaden the peak more (const. term effect)



※ For each Gaussian:

width ~ stochastic behavior: $\sigma \propto 1/\mathrm{sqrt}(1-x)$

※ Weight of superposition ~ x dist.

※ Const. term usually referred as "detector non-uniformity" or "mis-calibration".

Essence: shower-to-shower difference of sampling fraction

- Since x dist. also has E dependence (higher E → more hits → less fluctuation), this effect may contribute $1/\sqrt{E}$ term as well.

$$b_1(\xi) = \frac{q_0}{\sqrt{1 - q_1\,\xi}}$$

	Pixel	Chip
q_1	1.0	1.6

($q_1 = 1$ if with stochastic effect only)

Jet Energy Resolution

4 terms mainly contribute to JER:

$$\frac{\mathrm{rms}_{90}}{E} = \frac{21}{\sqrt{E}} \oplus 0.7 \oplus 0.004E \oplus 2.1\left(\frac{R}{1825}\right)^{-1.0}\left(\frac{B}{3.5}\right)^{-0.3}\left(\frac{E}{100}\right)^{0.3}\%$$

(M. Thomson 2008)

Calorimetry — Leakage — Tracker — Confusion(Nature of PFA)

※ Leakage, tracker terms are probably independent of ξ

The rest of slides show that

- The dead channel effect to "calorimetry term" is not serious
- At least in low E_j or low ξ region, where the confusion term does not seem to rise significantly, the simulation result looks reasonable.

Calorimetry term

Calorimetry term contribution can be (simply) estimated for each single jet by the error propagation of each jet particle energy measurement

For a jet consisting of N_c charged particles, N_γ photons and N_h neutral hadrons

$$\sigma_{\rm calo} \sim \sqrt{\sum_i^{N_c}(\sigma_c^i)^2 + \sum_i^{N_\gamma}(\sigma_\gamma^i)^2 + \sum_i^{N_h}(\sigma_h^i)^2}$$

$$\sim \sqrt{\sum_i^{N_\gamma}(\sigma_\gamma^i)^2 + \sum_i^{N_h}(\sigma_h^i)^2}$$

energy: E_c^i, E_γ^i, E_h^i

error: σ_c^i, σ_γ^i, σ_h^i (i=1,2, … ,N_c (N_γ,N_h))

Small contribution by charged particles can be neglected

$$\sigma_\gamma = E_\gamma \sqrt{b_0^2(\xi) + \left(\frac{b_1(\xi)}{\sqrt{E_\gamma}}\right)^2}$$

(ξ: dead rate)

$$\sigma_h = 0.71\sqrt{E({\rm GeV})}$$

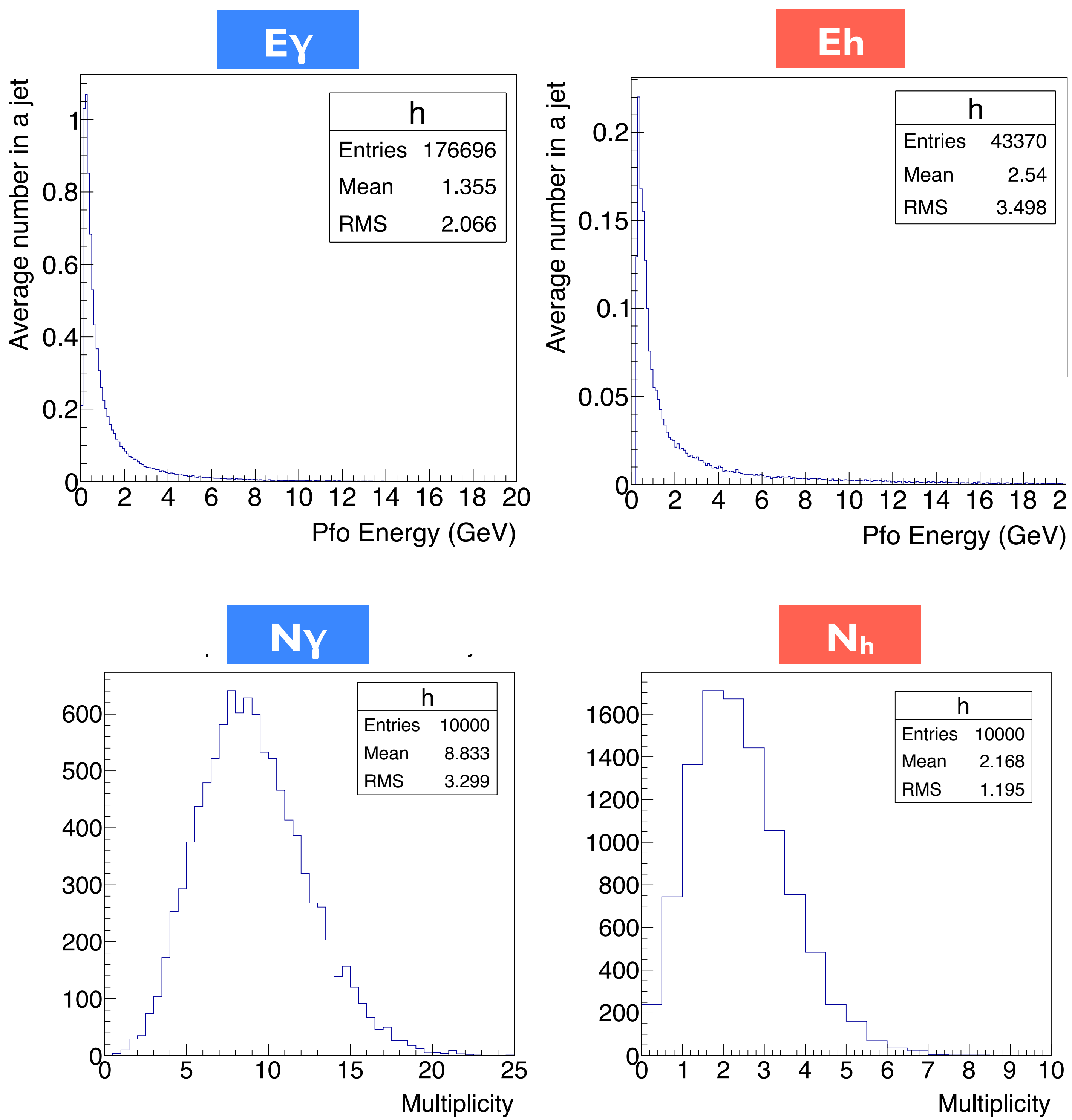
Chosen so that $\sigma_{\rm calo}$ is consistent to M.Thomson's value.

(usually referred to 0.55-0.60)

$$\frac{\rm rms_{90}}{E} = \frac{21}{\sqrt{E}}$$

Calorimetry term

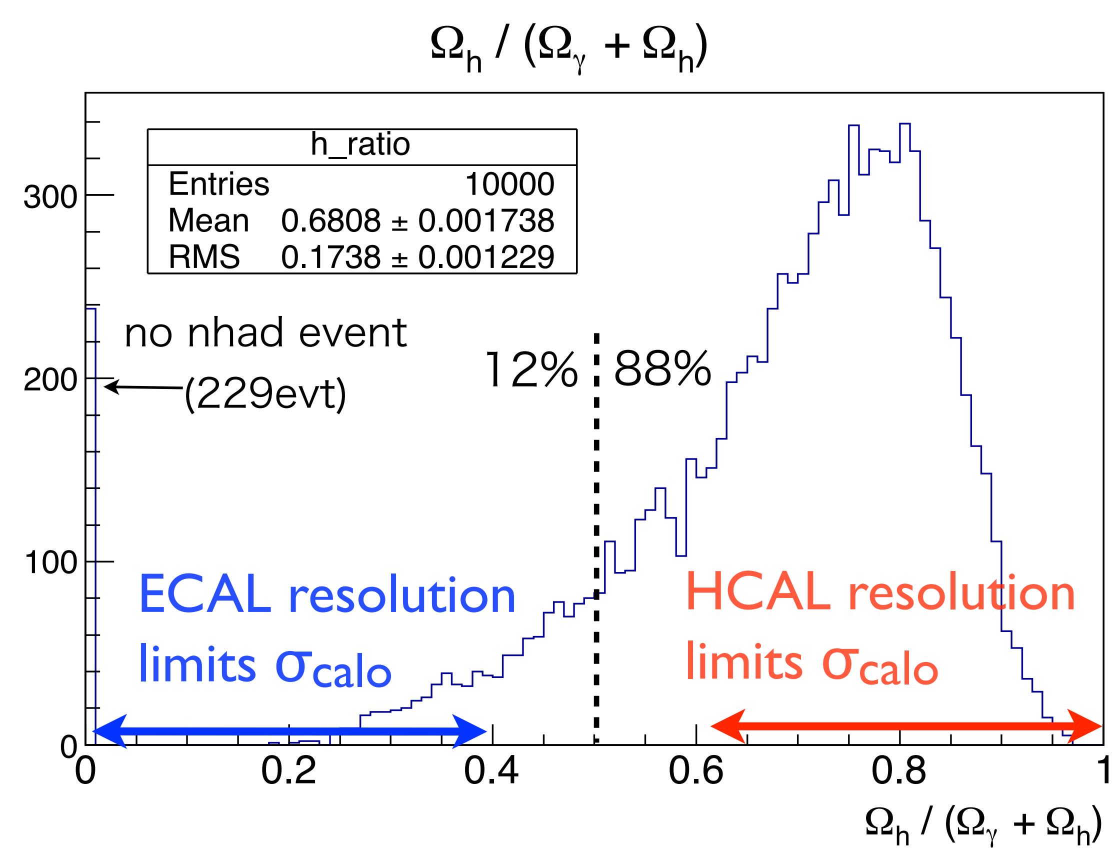
(45GeV jets sample /10000events)



However, contribution from σ_h is dominant in σ_{calo} for most of jets

$$\sigma_{\text{calo}} \sim \sqrt{\sum_i^{N_\gamma}(\sigma_\gamma^i)^2 + \sum_i^{N_h}(\sigma_h^i)^2}$$

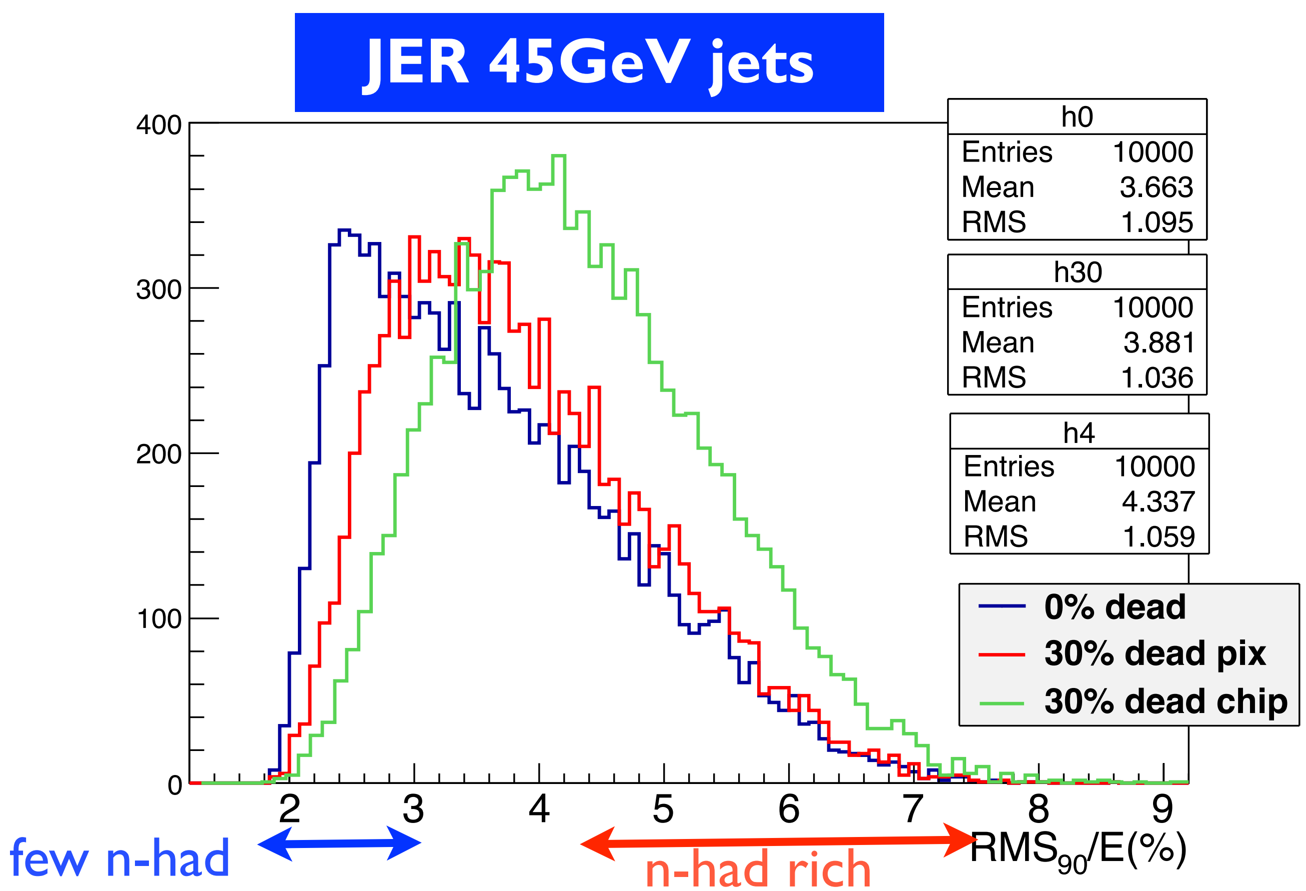
$$=: \sqrt{\Omega_\gamma^2 + \Omega_h^2}$$



ECAL resolution mainly affects jets with less neutral hadron energy contribution

Calorimetry term

JER can be calculated from σ_{calo}, for each jet with different combination of the components

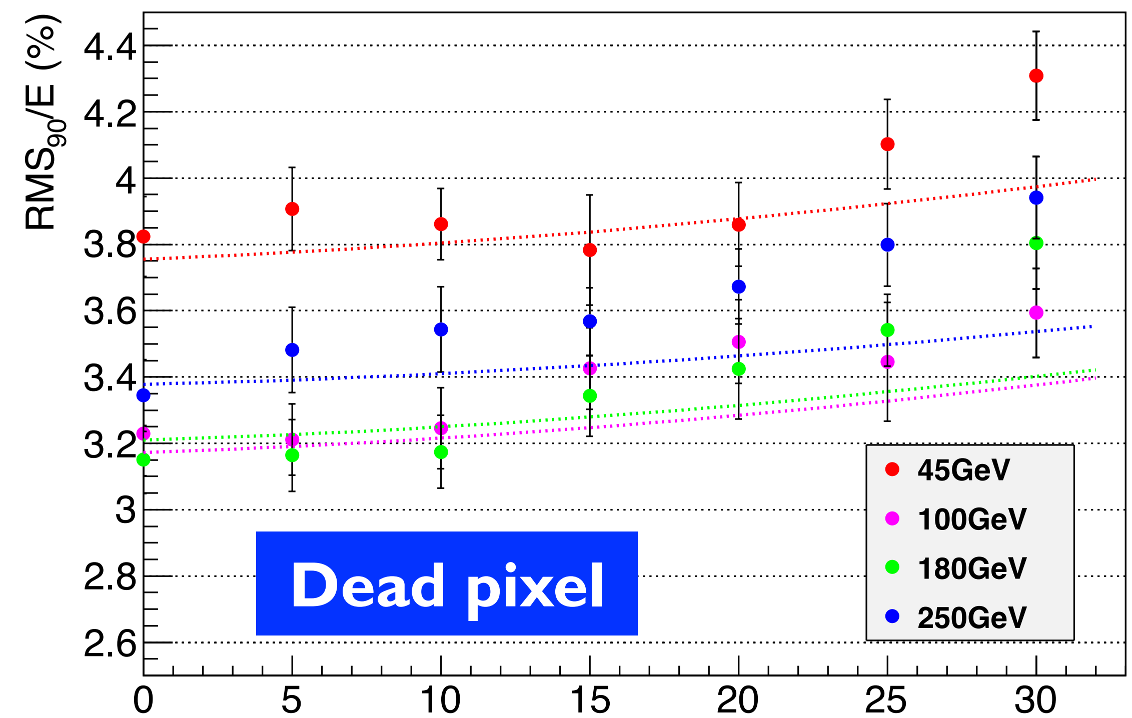


$$\mathrm{JER} = \frac{0.79 \times \sigma_{\mathrm{calo}}}{E_j} \bigoplus 0.7 \bigoplus 0.004 E_j \bigoplus 2.1 \left(\frac{E_j}{100}\right)^{0.3}$$

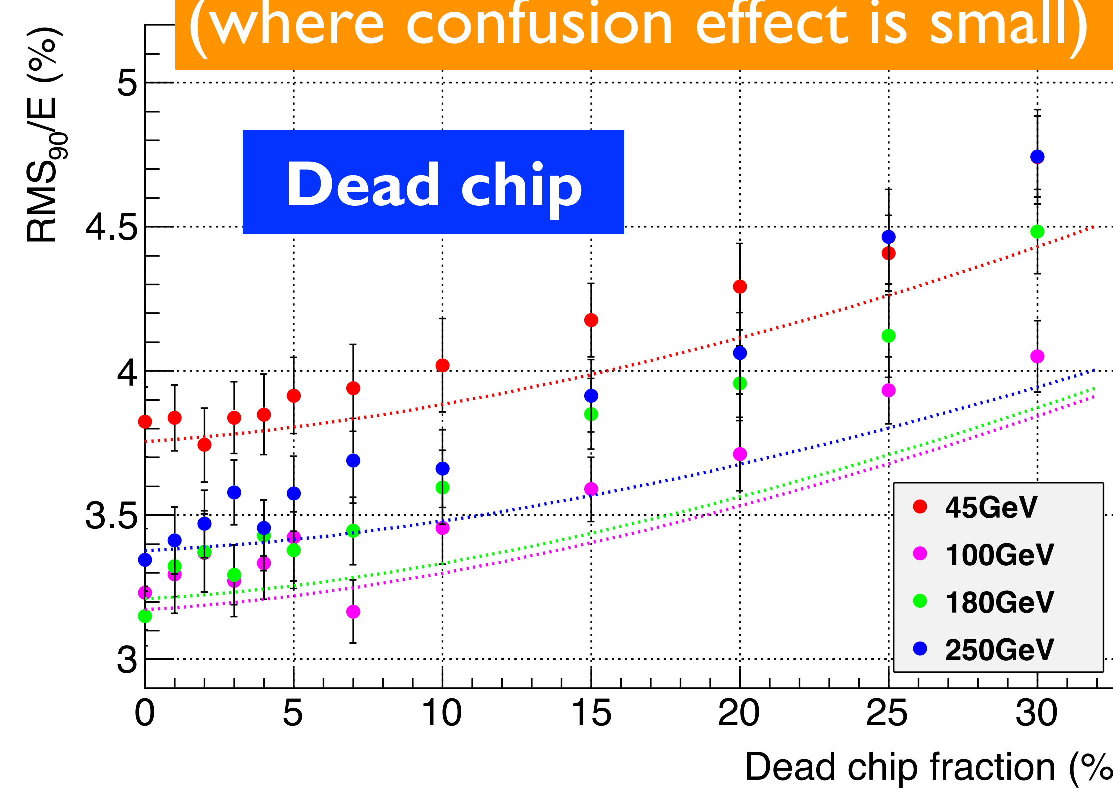
(if Gaussian) $\mathrm{RMS}_{90} = 0.79 \times \mathrm{RMS}$

ξ dep. of JER is calculated using the ξ dep. of ECAL obtained in page 7

JER growth when only ξ dependence in the calorimetry term is taken in (・ :simulation, ---: calculation)

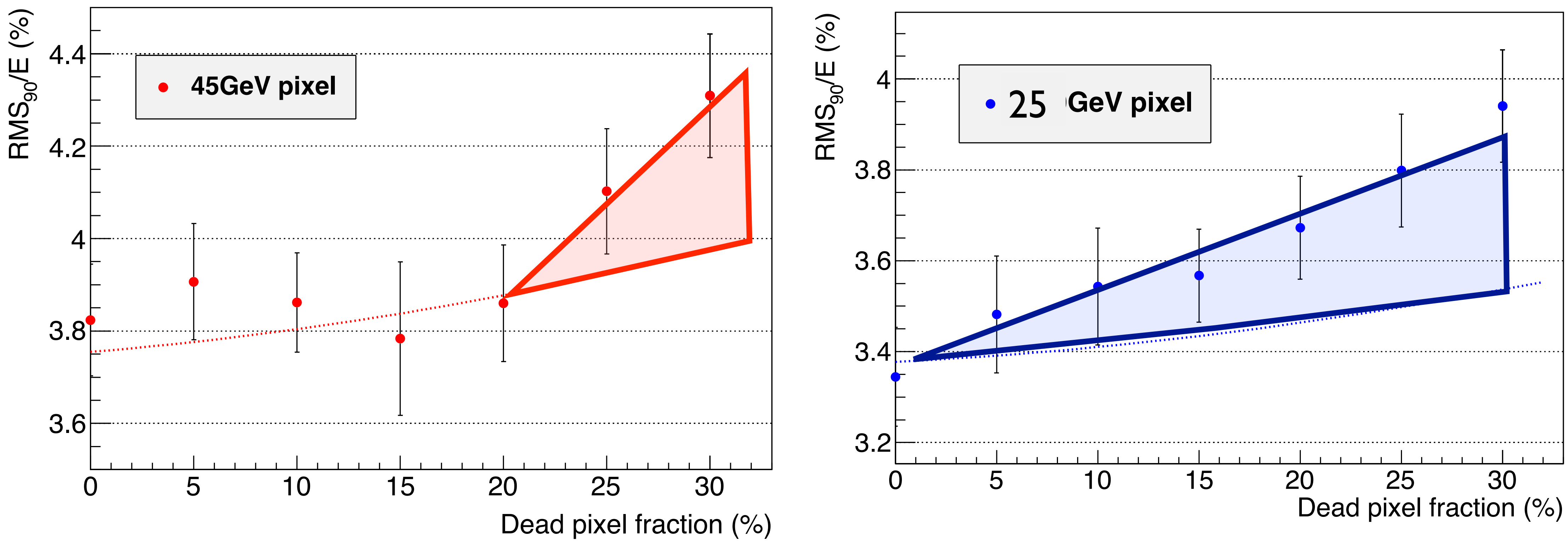


Well agree in low ξ / low E_j region (where confusion effect is small)



Confusion term

$$\mathrm{JER} = \frac{0.79 \times \sigma_{\mathrm{calo}}}{E_j} \bigoplus 0.7 \bigoplus 0.004E_j \bigoplus 2.1 \left(\frac{E_j}{100}\right)^{0.3}$$



Confusion becomes serious in high E jets, due to the closely overlapping showers.

(Already difficult to separate even with ξ=0. No allowance for dead channels)

While low energy jet showers seem to have some "allowance"?

(No problem with some effective granularity drop for good separation of showers)

Quantitate validation of this hypothesis is difficult... (statistics is too poor→grid?)

But this is highly consistent with our intuition!

Summary

- ECAL resolution does go worse

  The degrade is quantitatively evaluated

$$\sigma_\gamma = E_\gamma \sqrt{b_0^2(\xi) + \left(\frac{b_1(\xi)}{\sqrt{E_\gamma}}\right)^2}$$

(ξ: dead rate)

(pixel)

$$b_0(\xi) = 1.6\,(1 + 12\xi)\,(\%)$$

$$b_1(\xi) = \frac{17.4}{\sqrt{1-\xi}}\,(\%)$$

(chip)

$$b_0(\xi) = 1.6\,(1 + 28\xi)\,(\%)$$

$$b_1(\xi) = \frac{17.4}{\sqrt{1-1.5\xi}}\,(\%)$$

Small fraction of dead channels does not matter JER since

- ECAL resolution gives little influence on the calorimetry term in JER

  HCAL resolution set the limit for most of the jets

- (For low E jet) Confusion does not rise with some dead channels

  The allowance depends on Ej

Further implications

- Other dead channel models?

Non-uniform distribution (radiation damage etc.)

Dead sub-chip (4×4pix) etc.

⇒ The extent of degrade should be between uniform dead pix & uniform dead chip case

(The uniformity of sampling fraction is essential in thinking of dead effect!!)

- Schemes for recover resolution? (Restoration etc.)

As long as JER is concerned, not very necessary.

(>10% dead channels are not likely to be, damage to JER is limited)

But important for precise measurement of single photons (especially with high energy)

Also in case with local defect, restoration is more effective than just shifting calibration coefficient

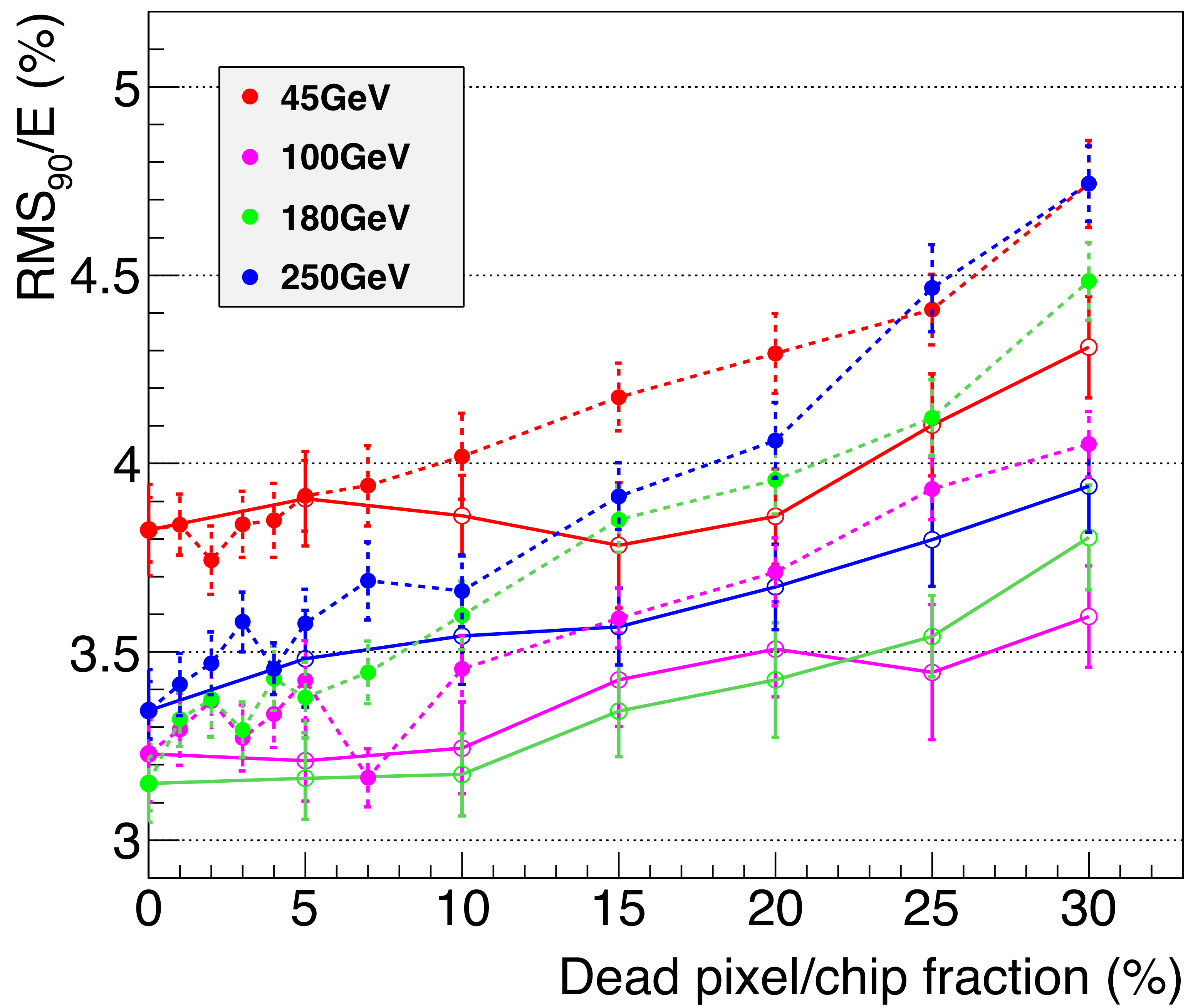
Backup

Combined plot

— pixed

--- chip

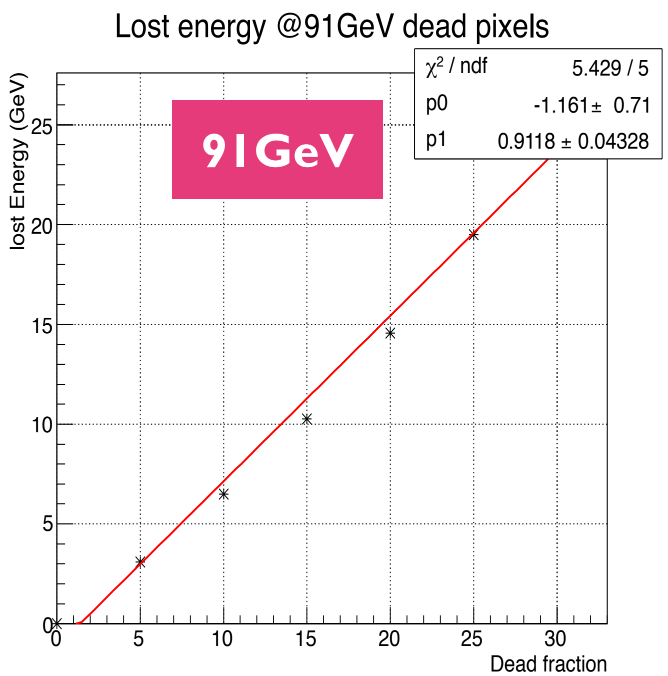
2000 evts for each point

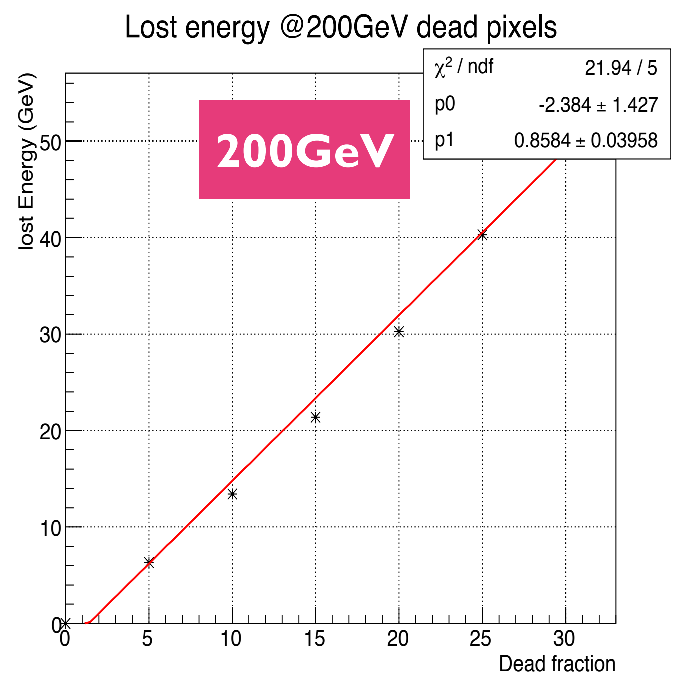


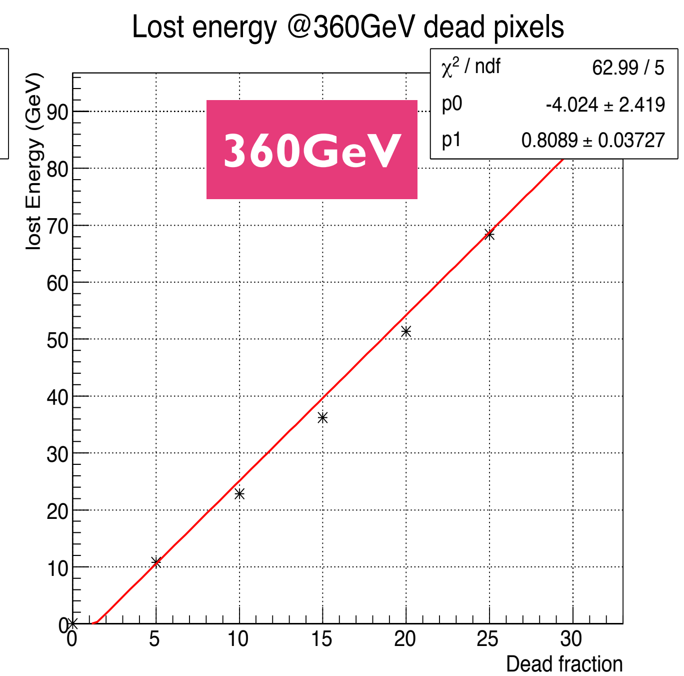
Unrecorded energy in ECAL (due to dead channels)

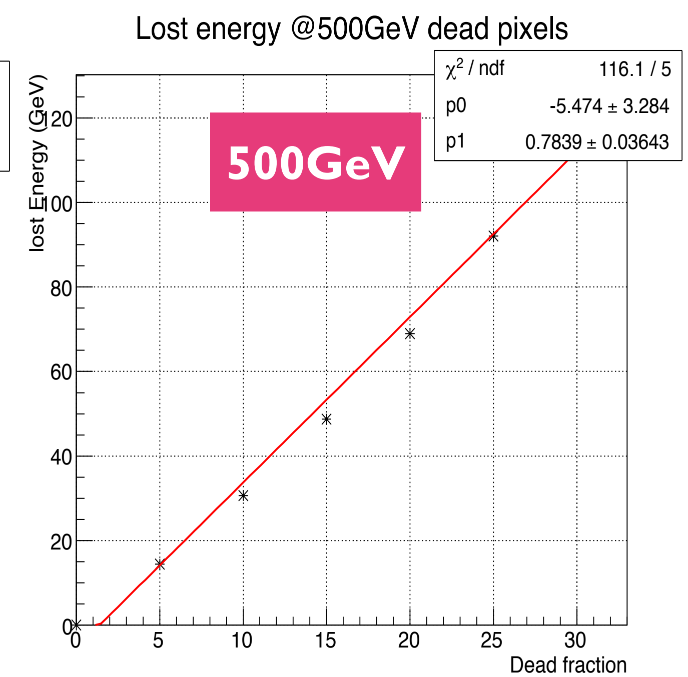
steepness <1 (jet particles does not deposit whole energy in ECAL), which varies along E

(Dead pixels, jet events)

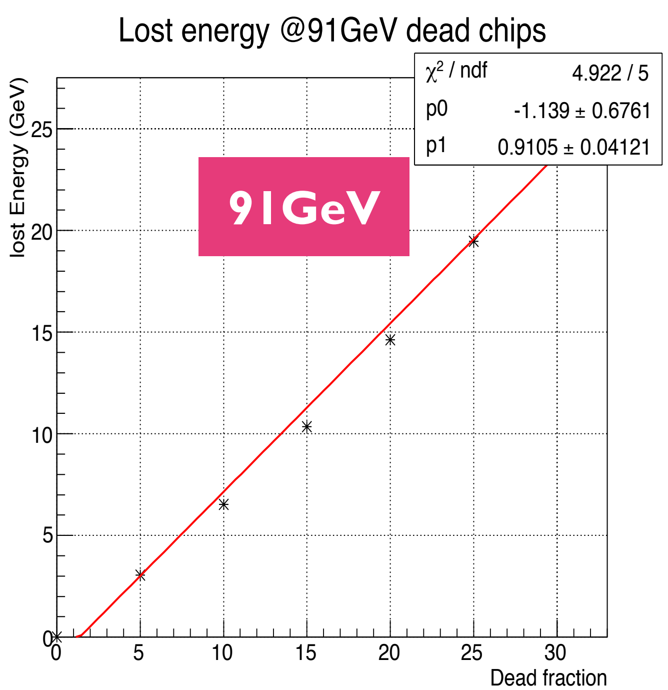




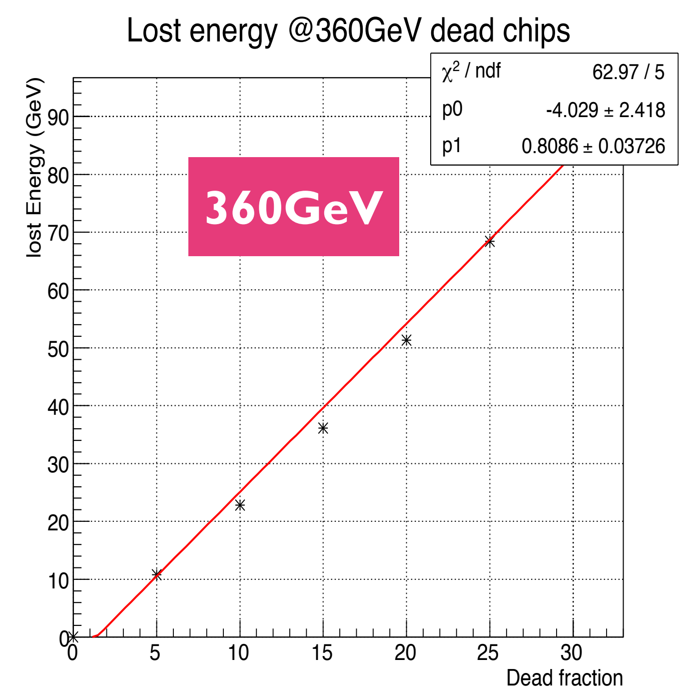


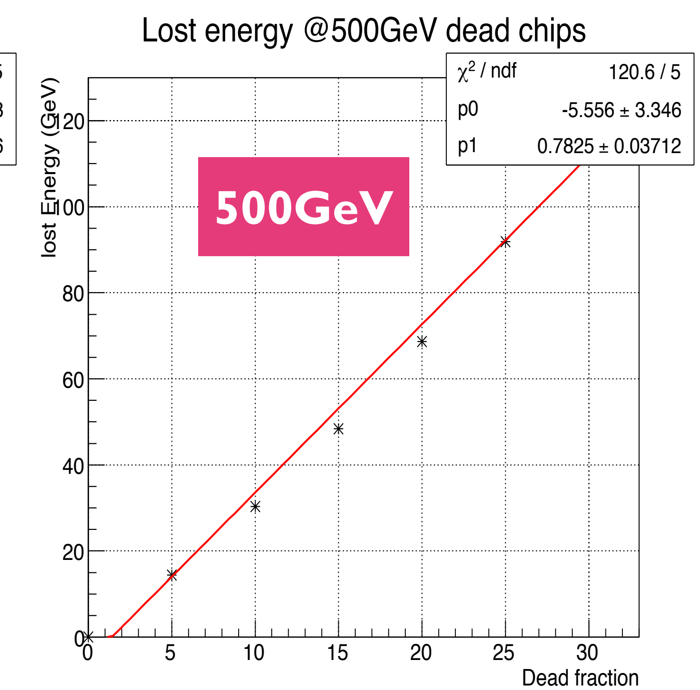


(Dead chips, jet events)



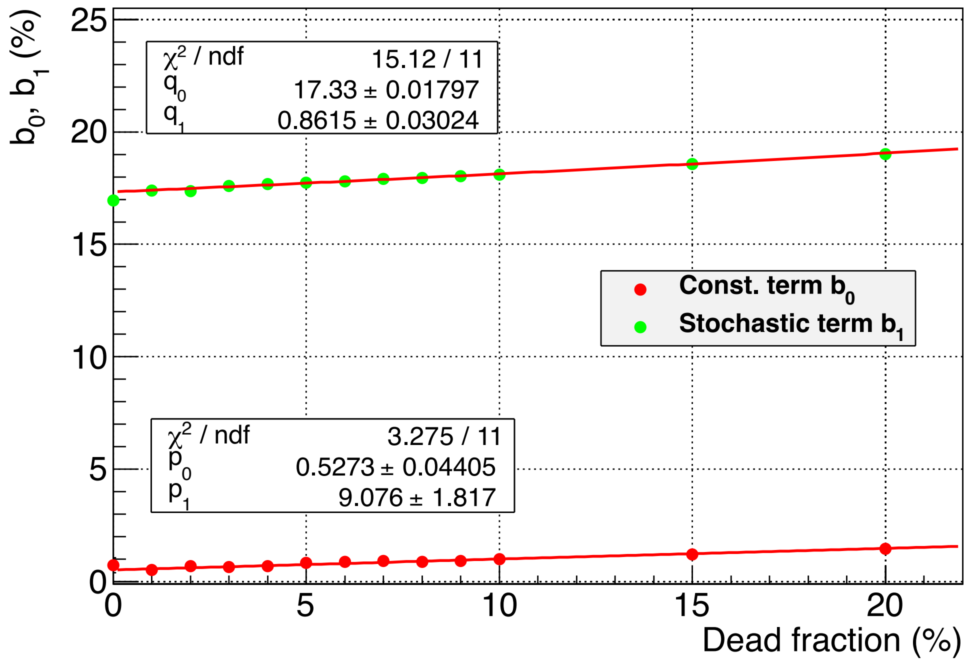
The file of 200GeV/dead chip was lost...



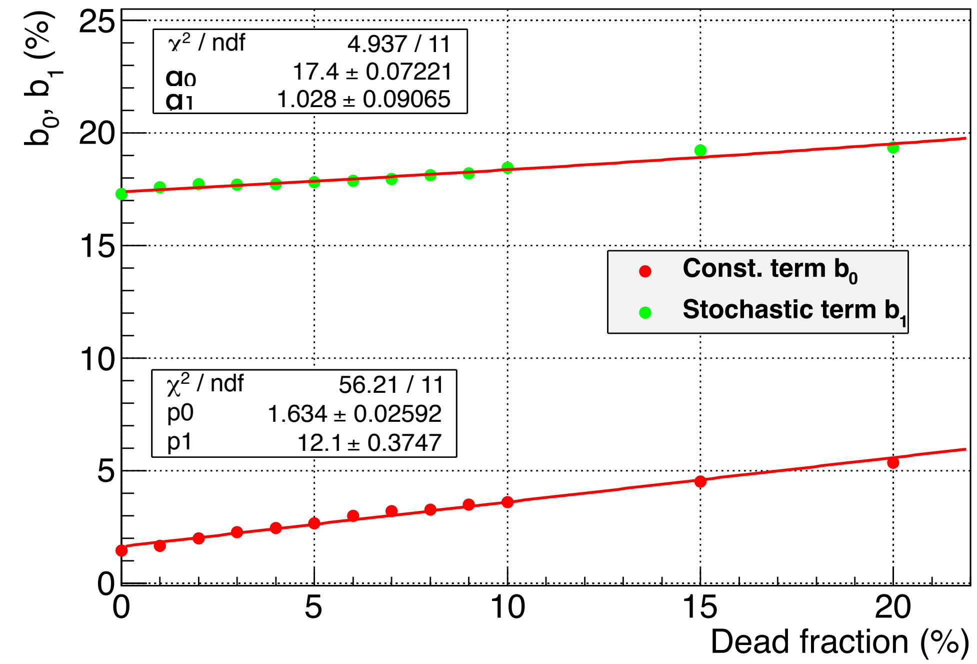


Hypothesis on stoch./const. term - backup by Toy MC

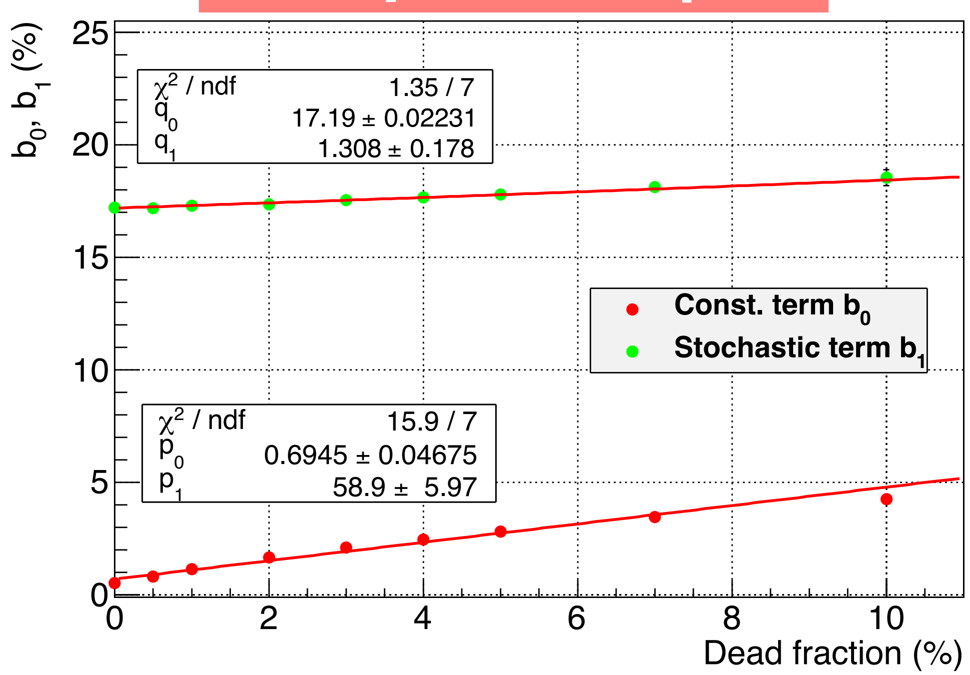
ToyMC / Pix



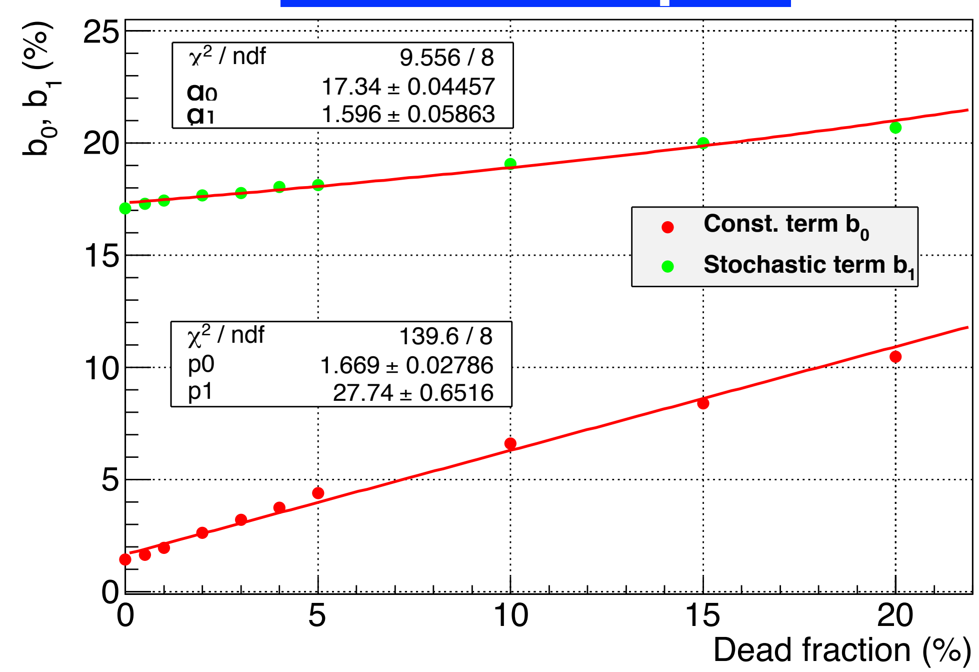
Dead Pixel



ToyMC / Chip



Dead Chip



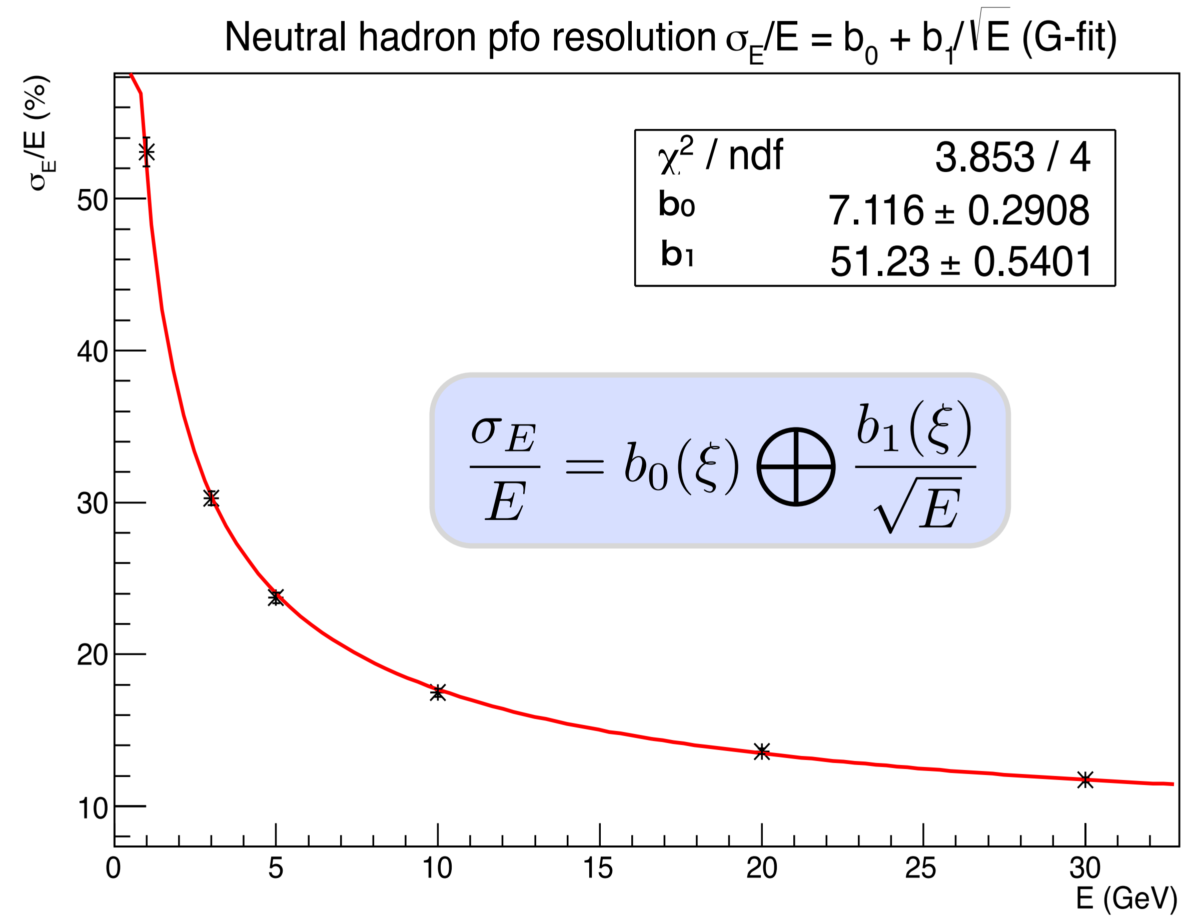
Tendency is reproduced?

The slope / offset are systematically small than simu.→ still some minor effect?

Neutral hadron resolution modeling

$$\sigma_h = 0.71\sqrt{E(\mathrm{GeV})}$$

0.71 is too large?

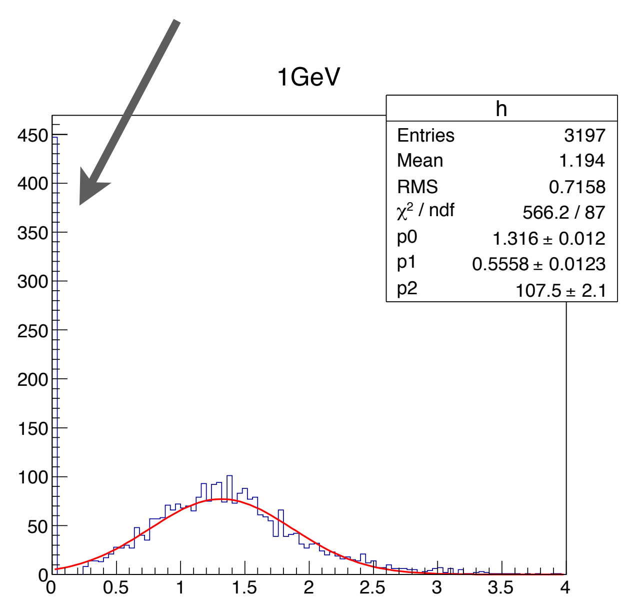


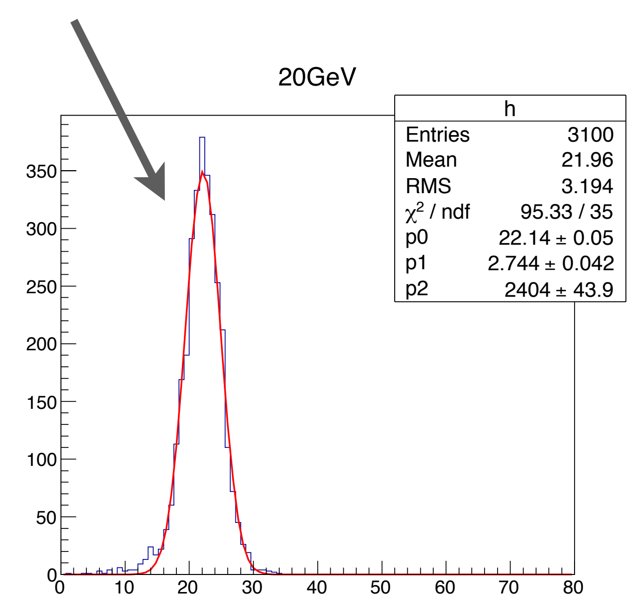
Tried to estimated by own using single K_L sample

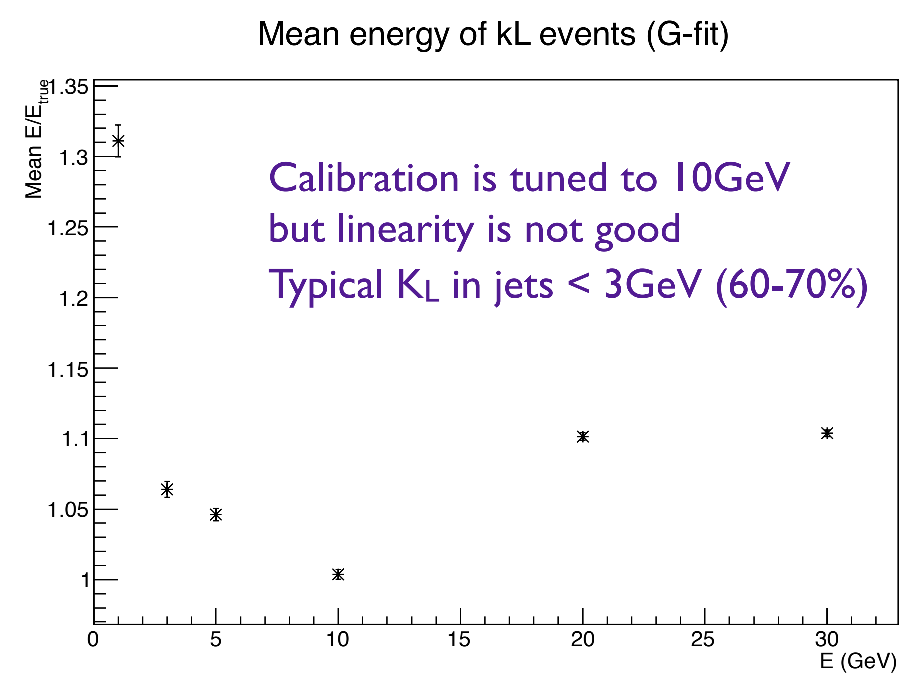
(cosθ<0.7, use events including only neutral hadron PFOs)

Well fit with const. term
Stochastic factor ~ 0.5?

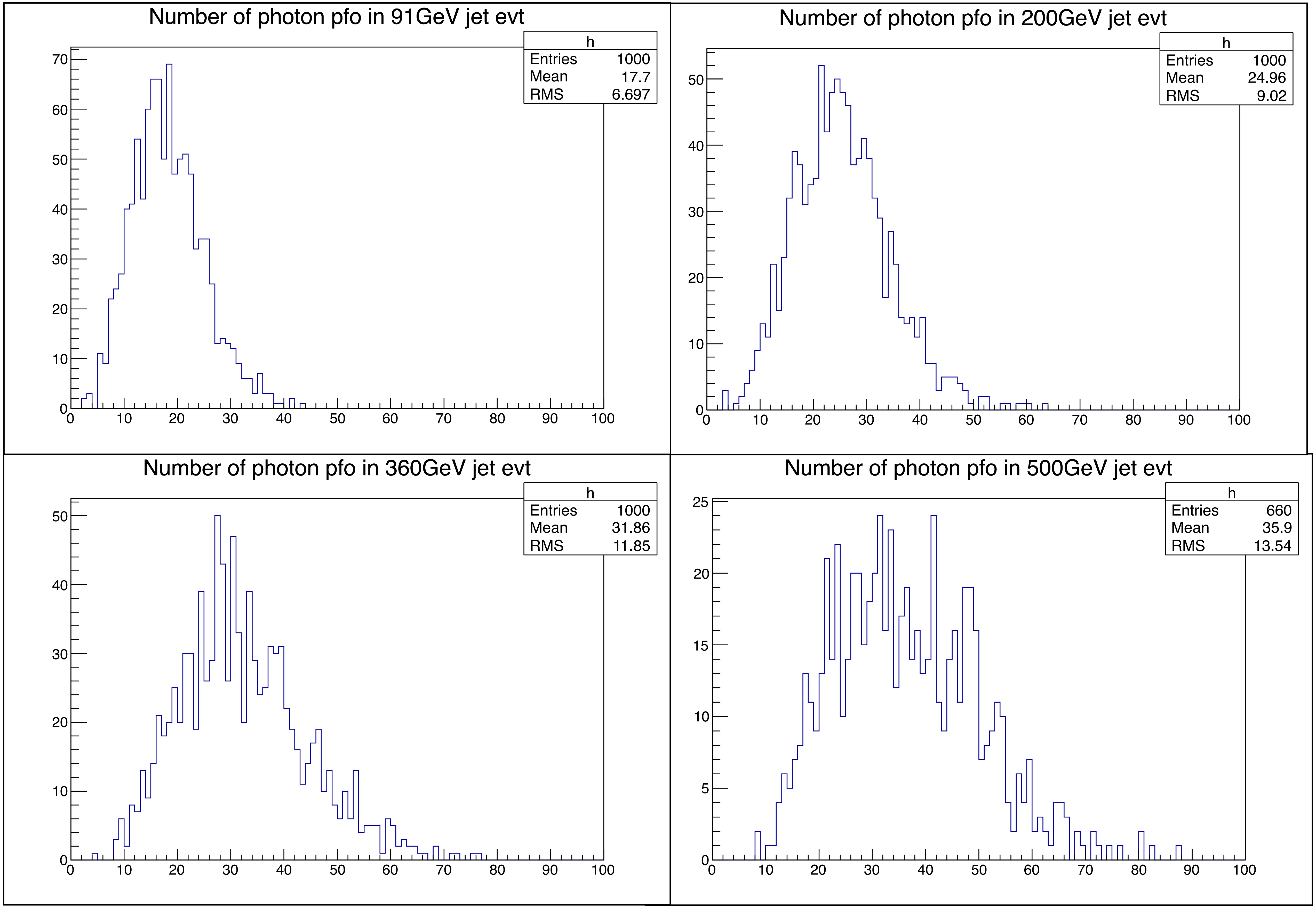
But many abnormal behaviors in energy distribution (0.71 as effective coeff. is possible?)
(0 energy events / wrong mean position)



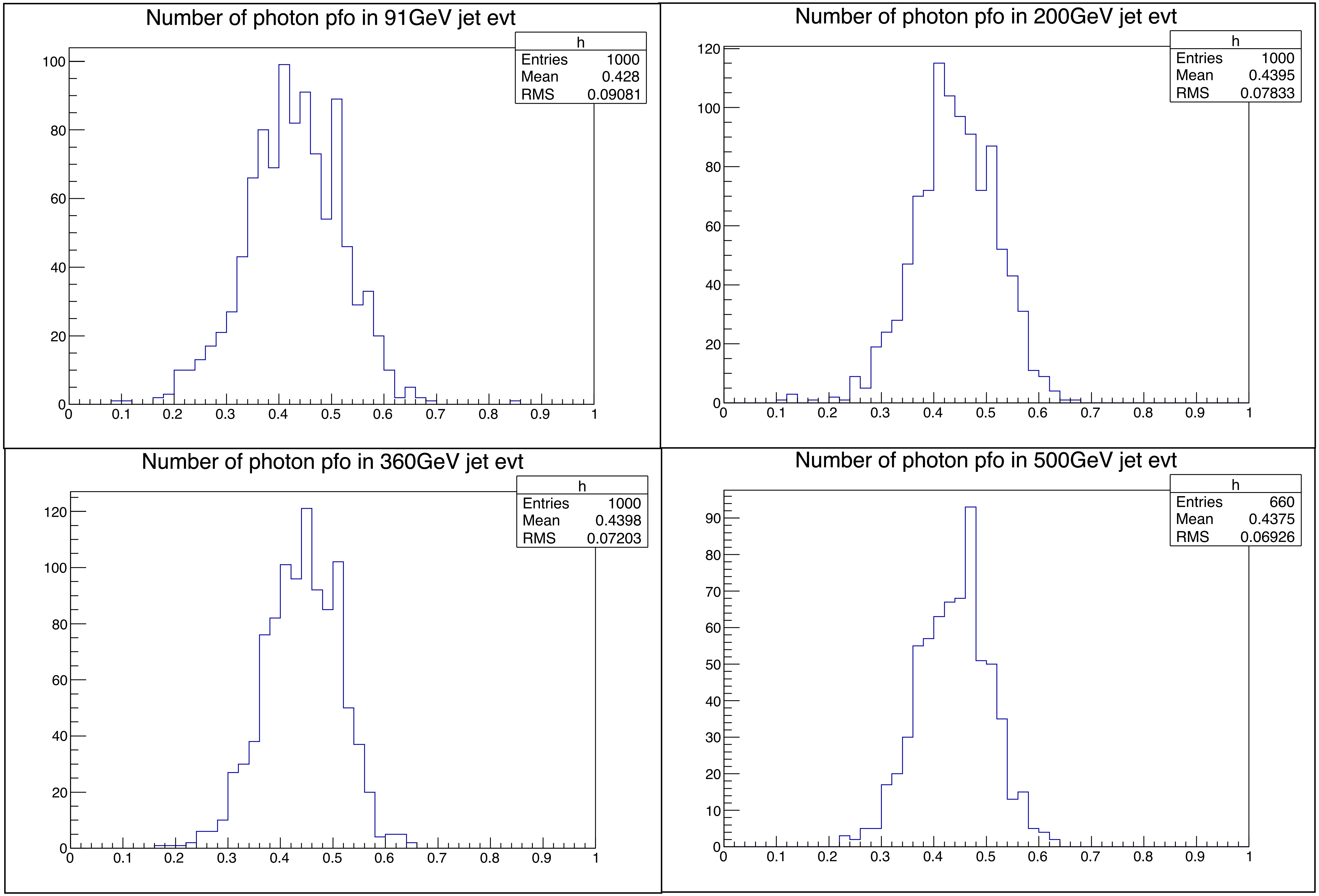




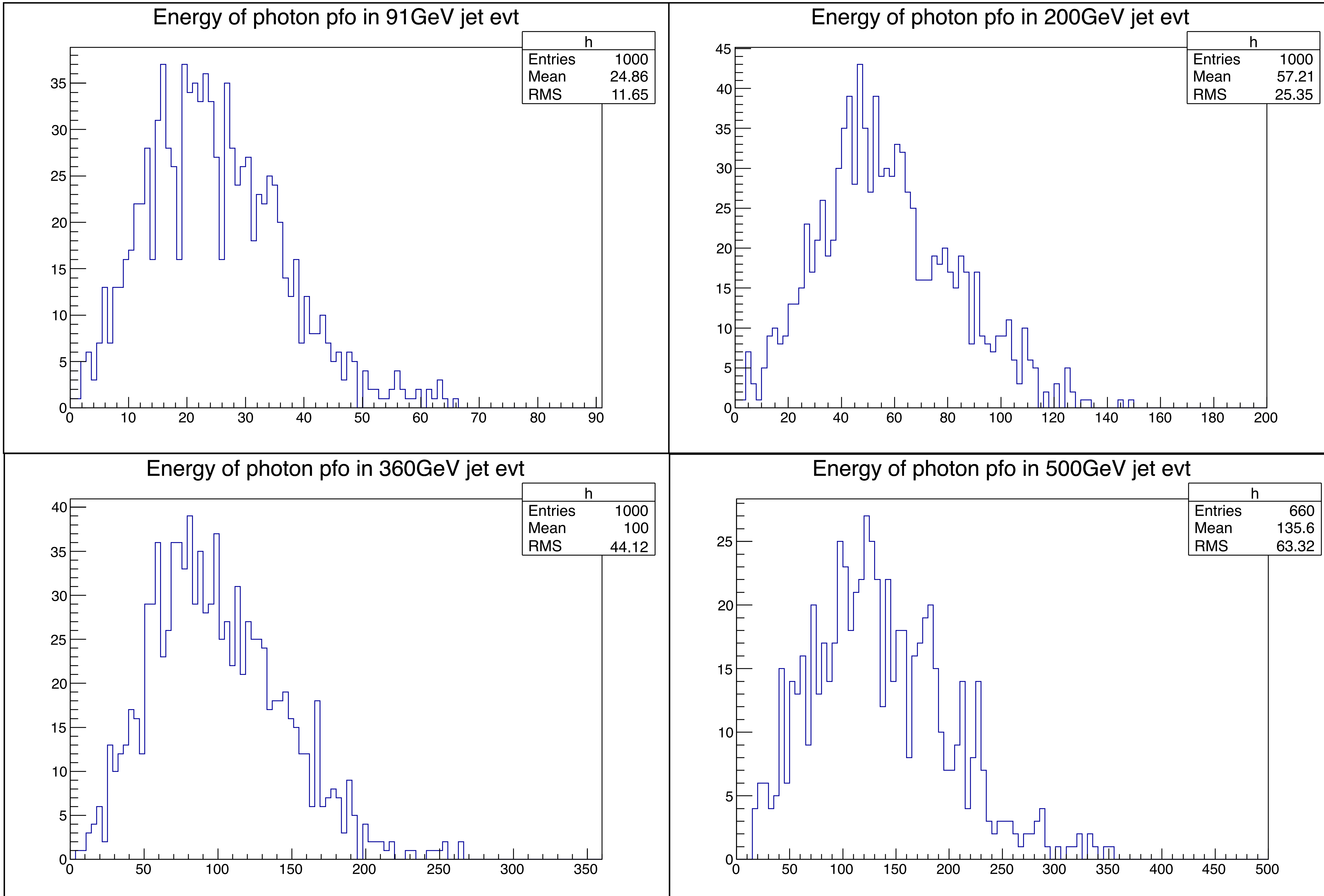
Number of photon pfo in a jet



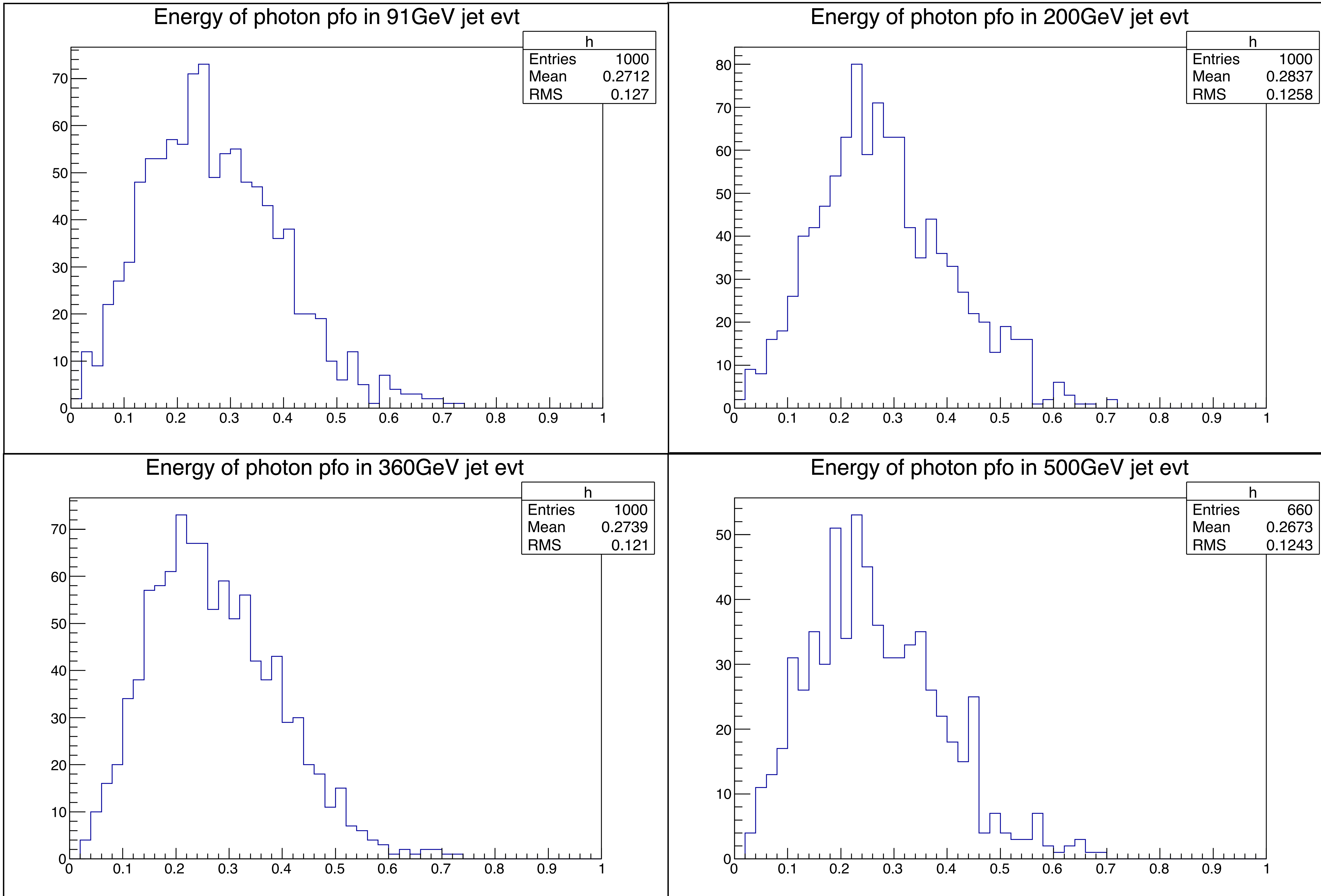
Number fraction of photon pfo in a jet



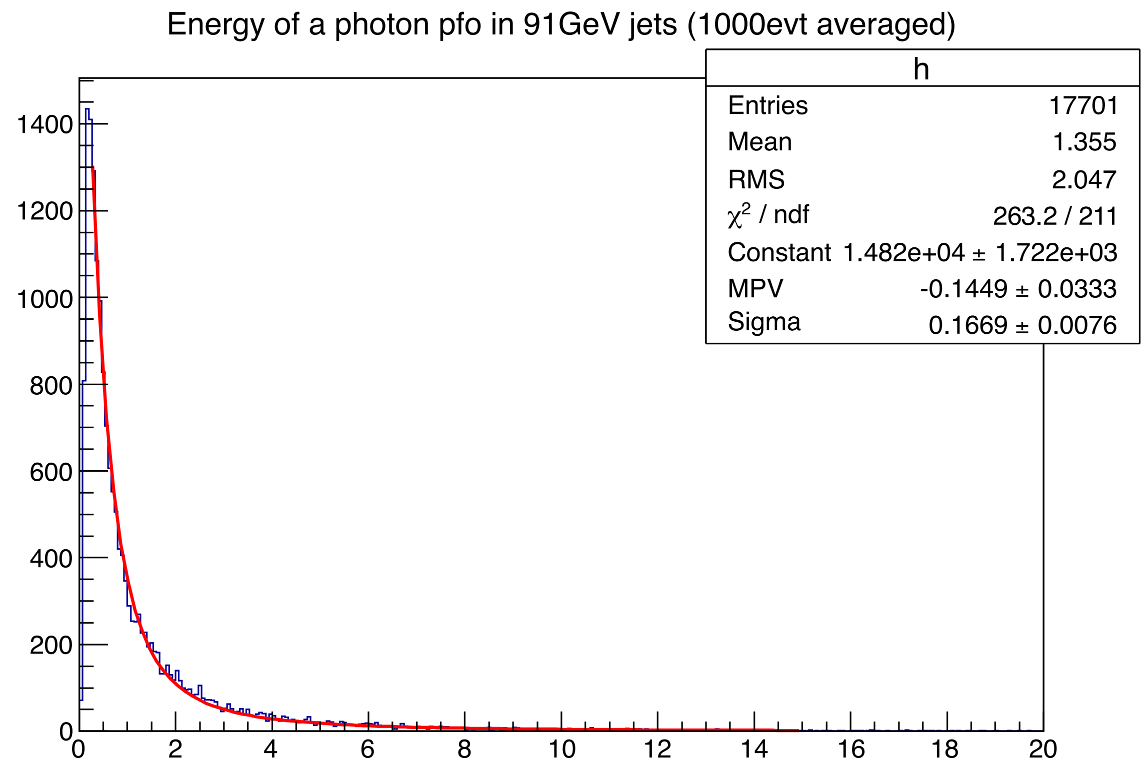
Photon Energy in a jet (GeV)

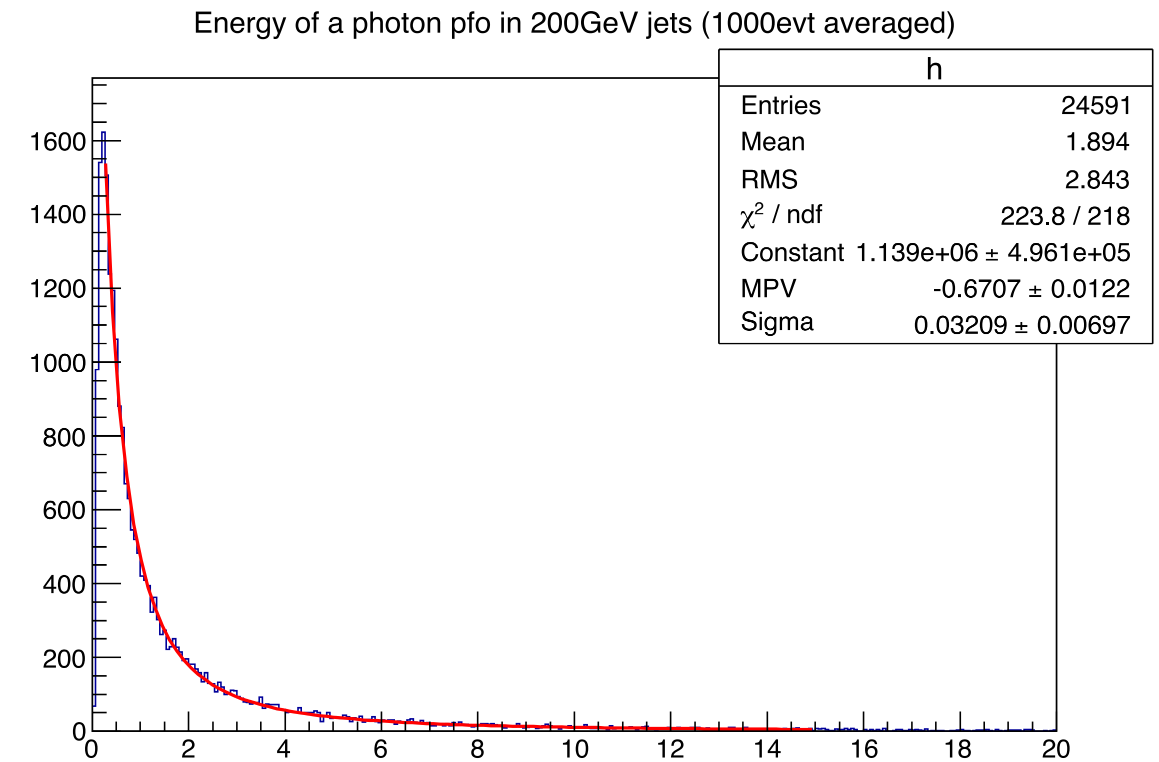


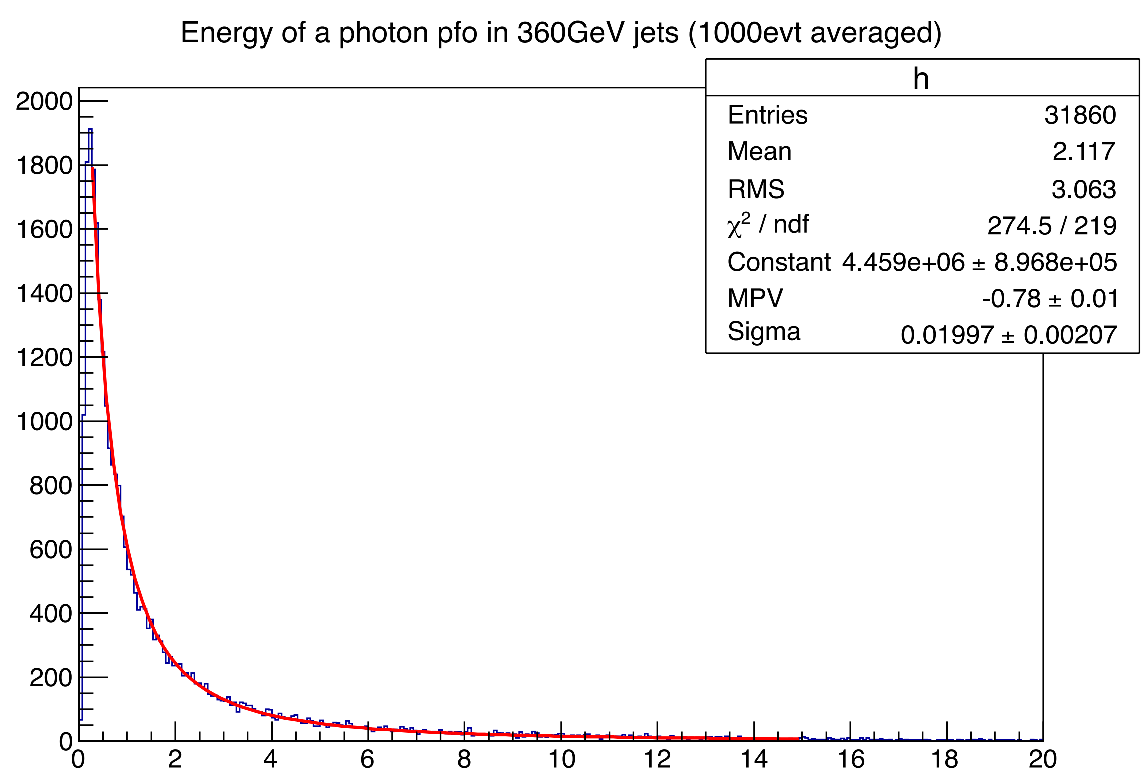
Photon Energy fraction in a jet

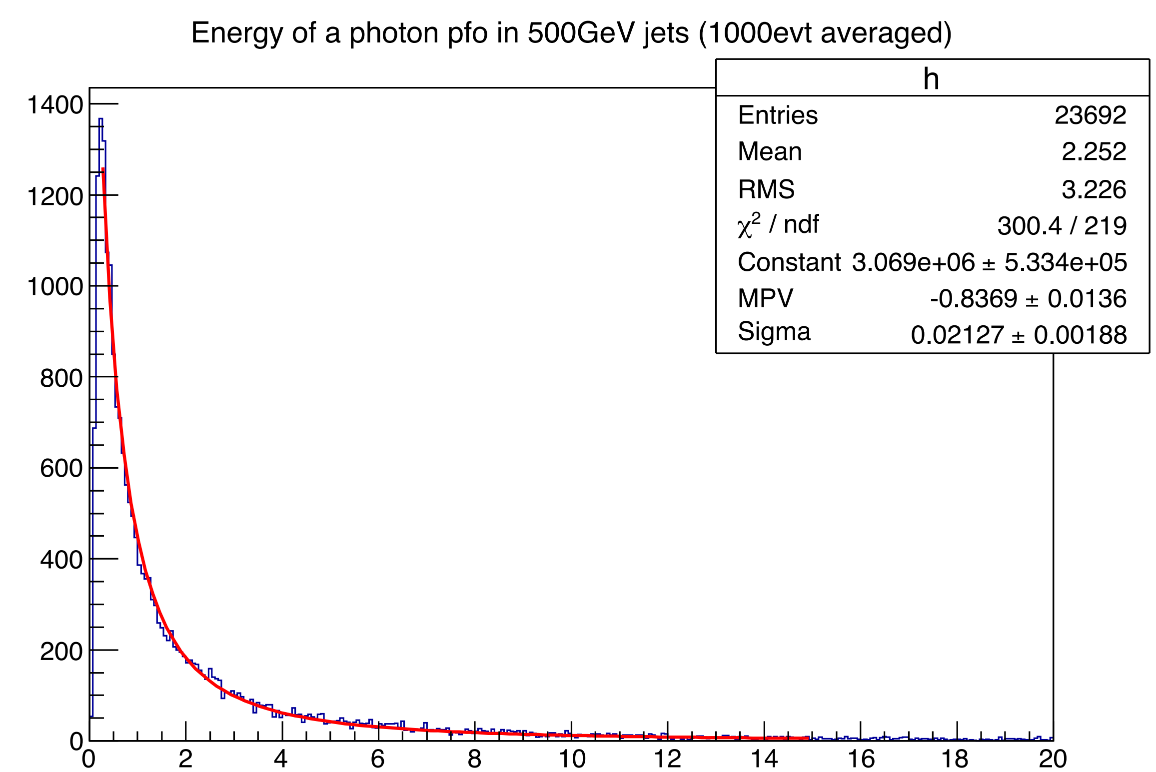


Energy of photon pfo in a jet (GeV)









@0.2~15GeV: Good fit by Landau tail

Energy of photon pfo in a jet (GeV)

Percentage of photon pfo which has energy lower than 2,3,4,10GeV

Single Jet Energy

	45.5GeV	100GeV	180GeV	250GeV
<2GeV	81.4	73.3	69.2	66.7
<3GeV	88.7	81.6	77.7	75.6
<4GeV	92.3	86.1	82.8	80.7
<10GeV	98.5	95.6	93.5	92.2