Impact of the Fluorescence Yield selection on the reconstructed shower parameters

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Outline

- Introduction
- Impact of the Fluorescence Yield dataset on reconstructed shower parameters
  - Comparison of Auger, HiRes and TA databases
  - Results on E and X_{max}
- Impact of uncertainties of quenching parameters

INTRODUCTION

Fluorescence yield

Y_λ is defined as the number of λ photons emmited per unit of deposited energy (ph/MeV)

$$Y_\lambda = \frac{Y_\lambda^0}{1 + P/P'_\lambda}$$

P' values determine the dependence of the fluorescence yield with atmospheric properties

$$\frac{1}{P'} = \frac{f_{N_2}}{P'_{N_2}} + \frac{f_{O_2}}{P'_{O_2}} + \frac{f_w}{P'_w}$$

P' contains contributions from all possible quenchers

$$P'_i = \frac{\sqrt{\pi \mu_{Ni} k T}}{\sqrt{8}\tau_0 \sigma_{Ni}} \qquad \sigma_{Ni} \propto T^\alpha \qquad P'_i \propto T^{\frac{1}{2}-\alpha}$$

P' depends on temperature

FY Dataset

The reconstruction of the shower parameters requires:

1.- Absolute values in dry air for all wavelengths, $Y_\lambda (P_0, T_0)$ or alternatively $Y_{ref}(P_0,T_0)$ and $I_\lambda(P_0,T_0)$.

2.- $P'_\lambda(T_0)$ for dry air

3.- T dependence of collisional cross section, α_λ

4.- P'_w for all wavelengths (and its α_w values if possible).

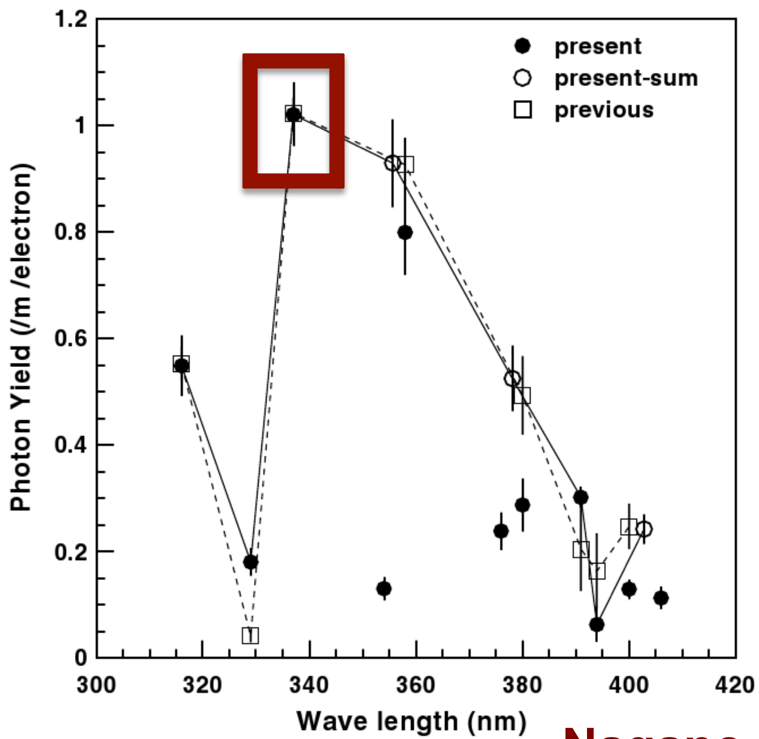
Y_λ at any given P, T conditions can be obtained from:

$$Y_\lambda(P,T) = Y_\lambda\left(P_0,T_0\right)\frac{1+P_0/P'_\lambda\left(T_0\right)}{1+P/P'_\lambda\left(T\right)}$$

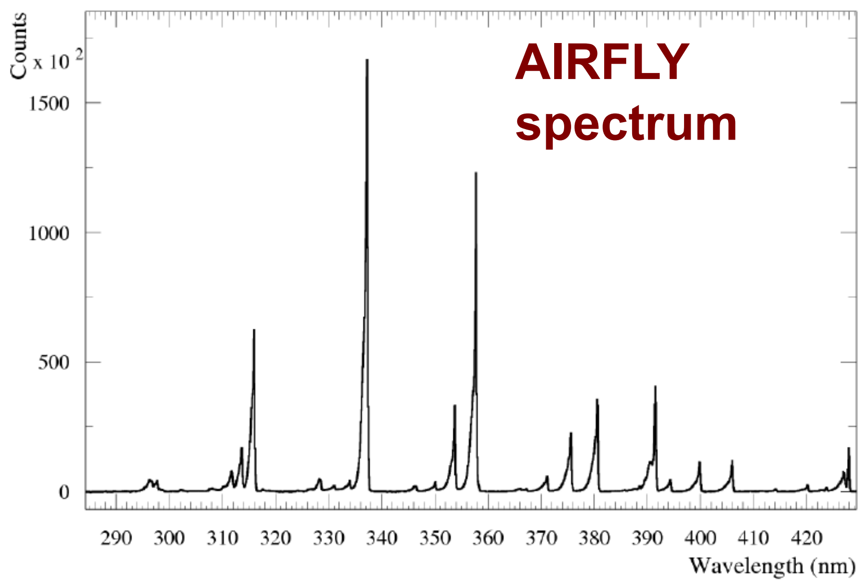
IMPACT OF DATASET SELECTION ON RECONSTRUCTED SHOWER PARAMETERS

I.- Auger Dataset

- Absolute value of Y_{337} at 1013 hPa and 293 K by Nagano.
- Relative intensities and P' for 34 bands measured by AIRFLY.
- α parameter measured by AIRFLY for 14 bands
- P'_w measured by AIRFLY for 14 bands



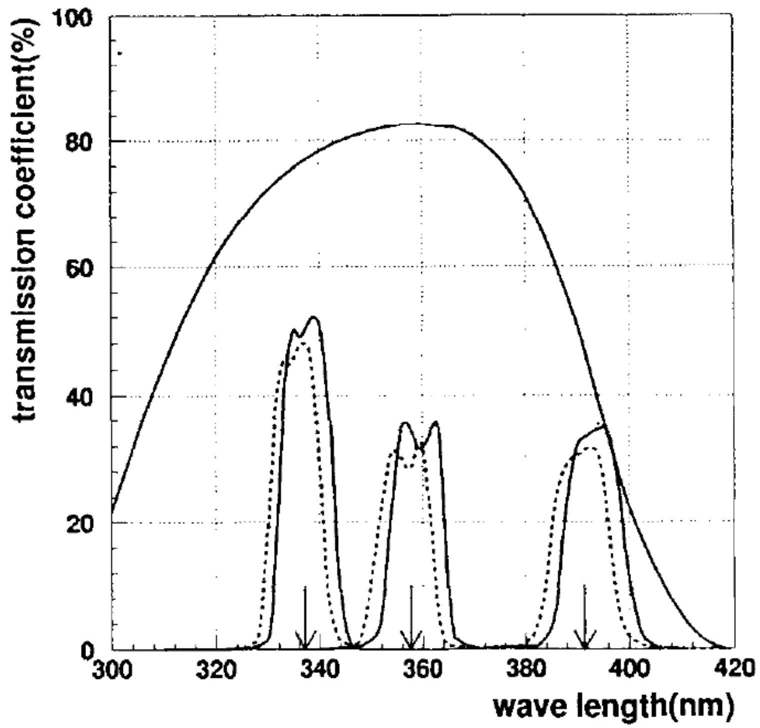
Nagano Measurement



AIRFLY spectrum

II.- HiRes Dataset

-Absolute value of Y_{337}, Y_{357} and Y_{391} at 1013 hPa and 293 K by Kakimoto.
- Relative intensities for the remaining bands distributed according to Bunner spectrum.
- P' values from Kakimoto.
- No T, h effects

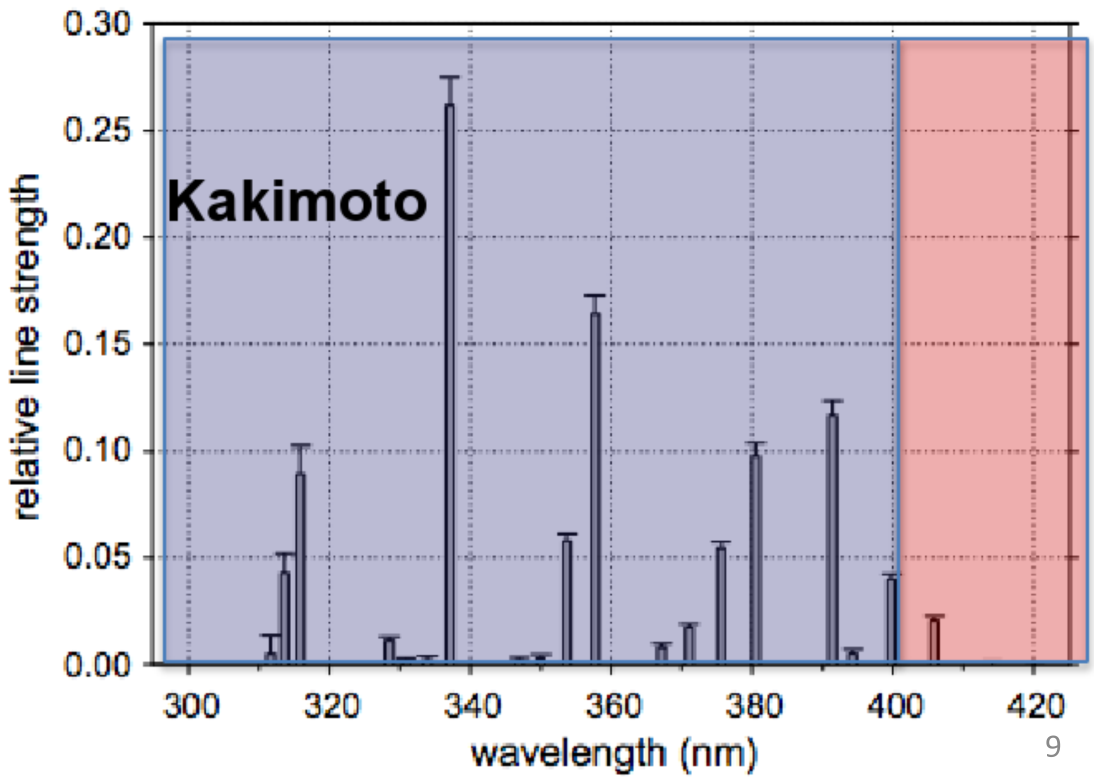


Kakimoto measurement

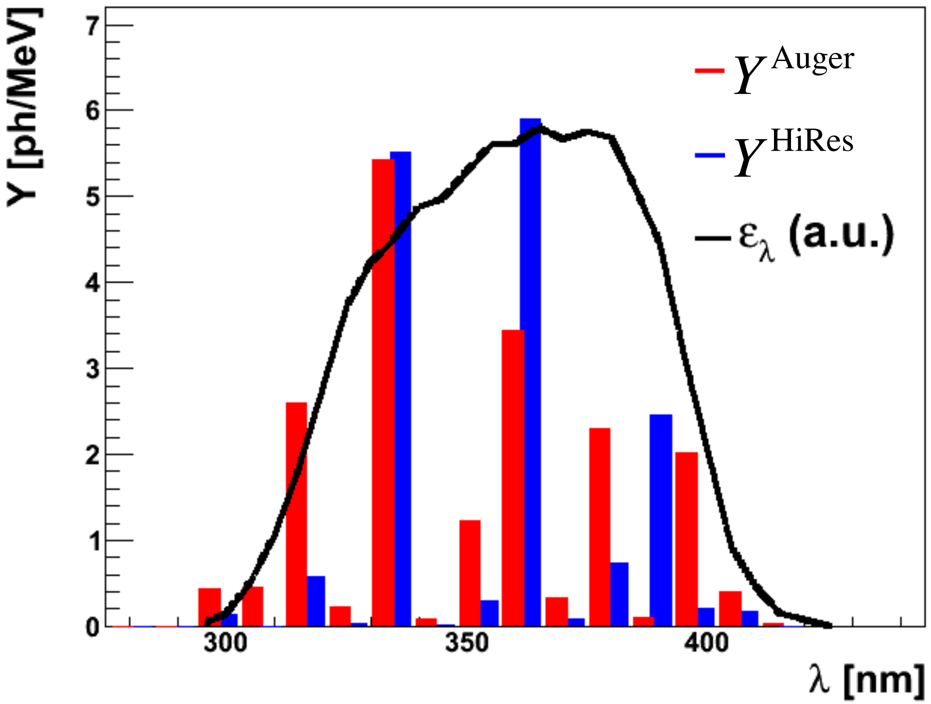
III.- Telescope Array Dataset

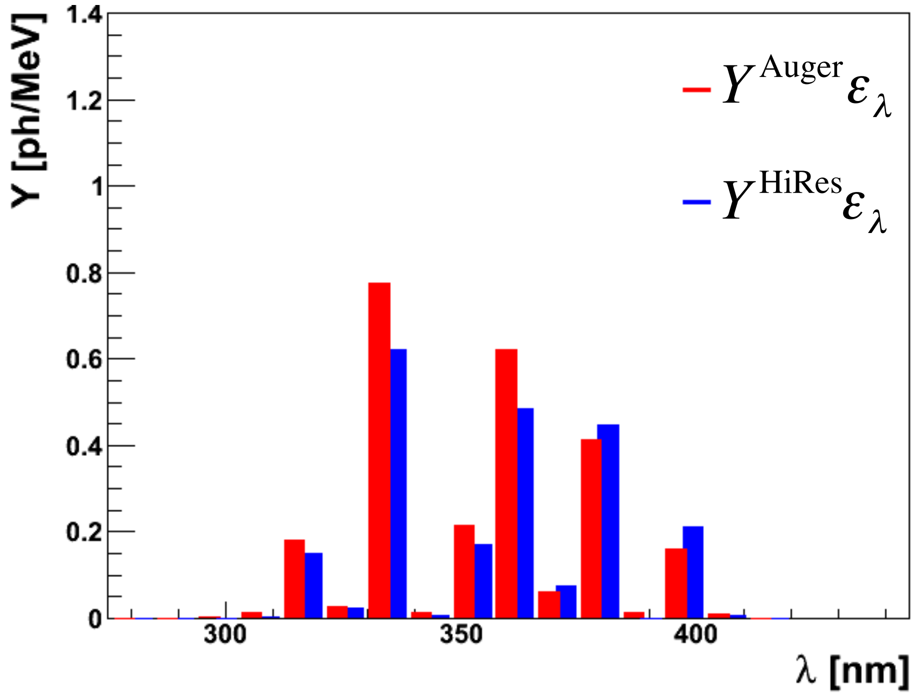
- Absolute value of Y (300 – 420 nm) at 1013 hPa and 293 K
    - Y (300 – 400 nm) from Kakimoto
    - Y (400 – 420 nm) from FLASH
- Relative intensities measured for 20 bands by FLASH.
- P' values from Kakimoto.
- No T,h effects

FLASH spectrum



Comparison of FY: HiRes vs Auger





Ratio of total yields

$$Y^{HiRes}/Y^{Auger} = 0.82$$

Ratio including optical eficiency

$$Y^{HiRes}/Y^{Auger} = 0.98$$

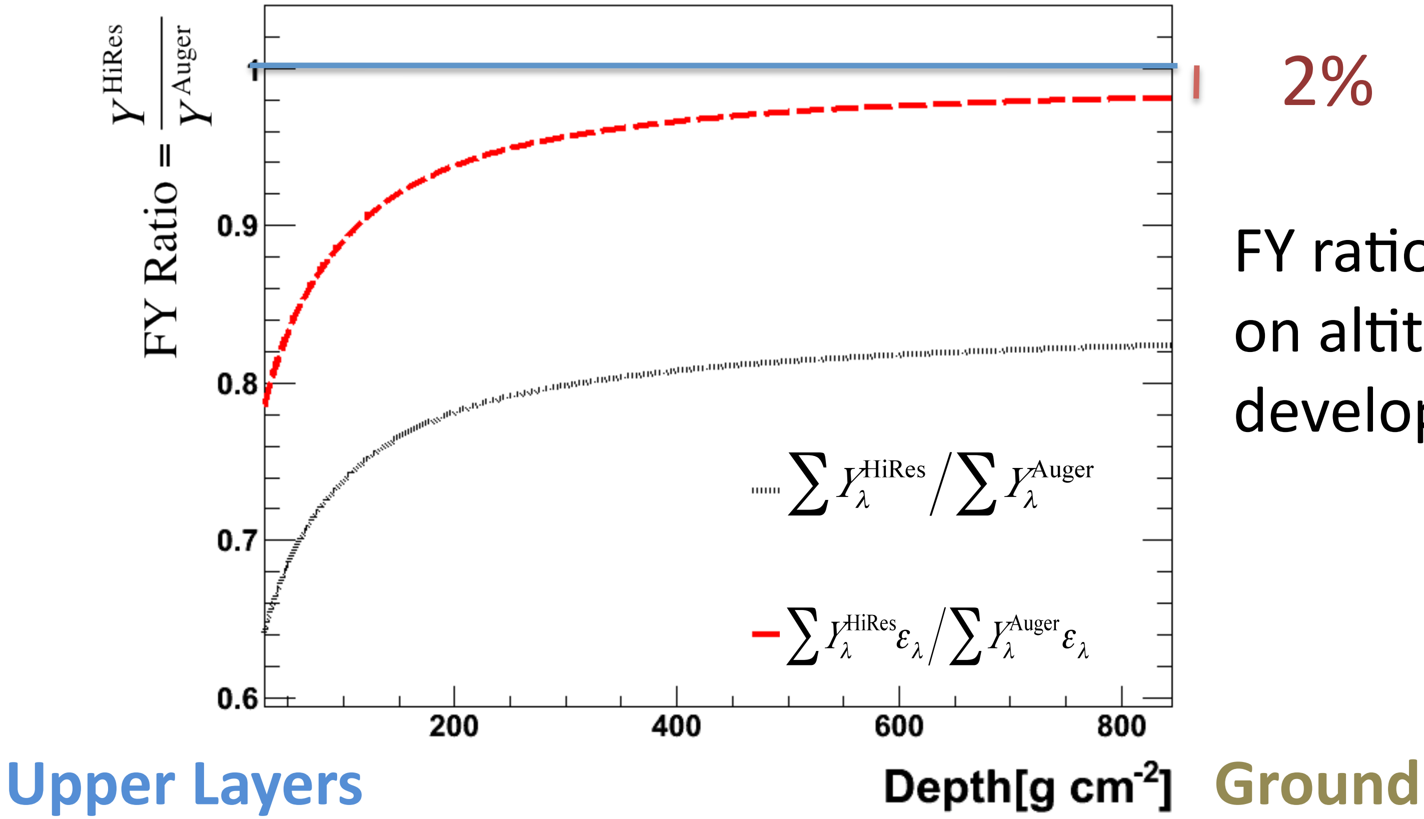
Difference between HiRes and Auger significantly reduced when optical efficiency is included

Y^{Auger} does not take into account T,h effects

Comparison of FY: HiRes vs Auger

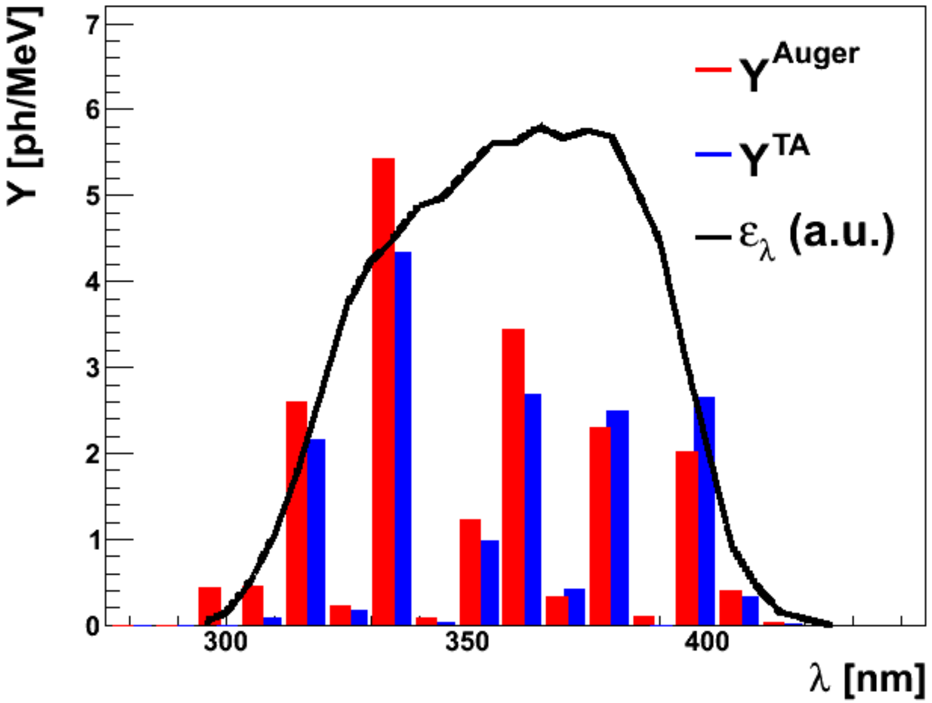
Y^{Auger} = fluorescence yield from the Auger dataset (no T, h)

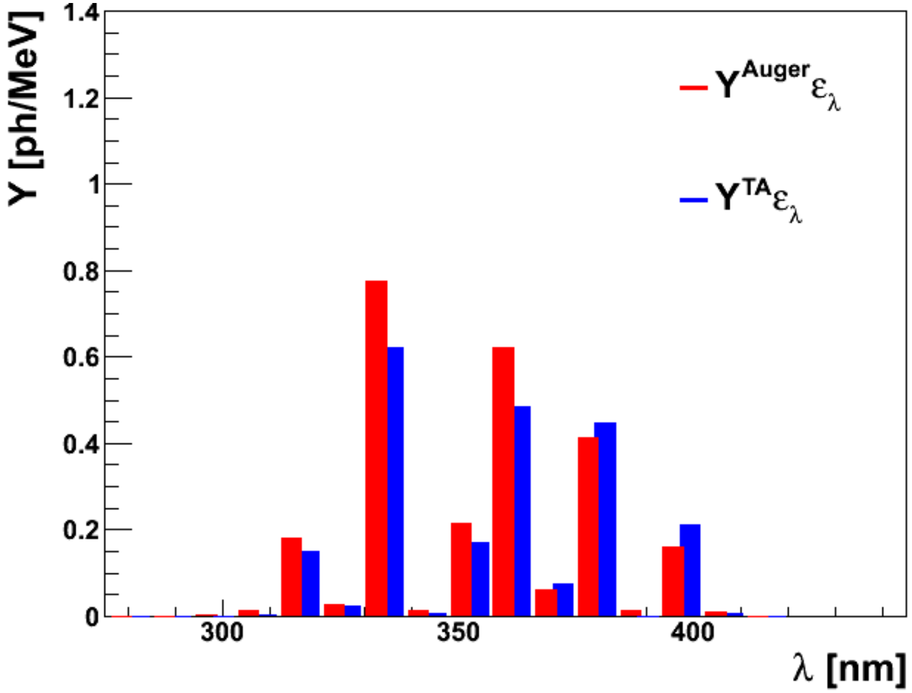
Y^{HiRes} = fluorescence yield from the HiRes dataset



FY ratio is independent on altitude in the shower development region

Comparison of FY: TA vs Auger





Ratio of total yields

$$Y^{TA}/Y^{Auger} = 0.83$$

Ratio including optical eficiency

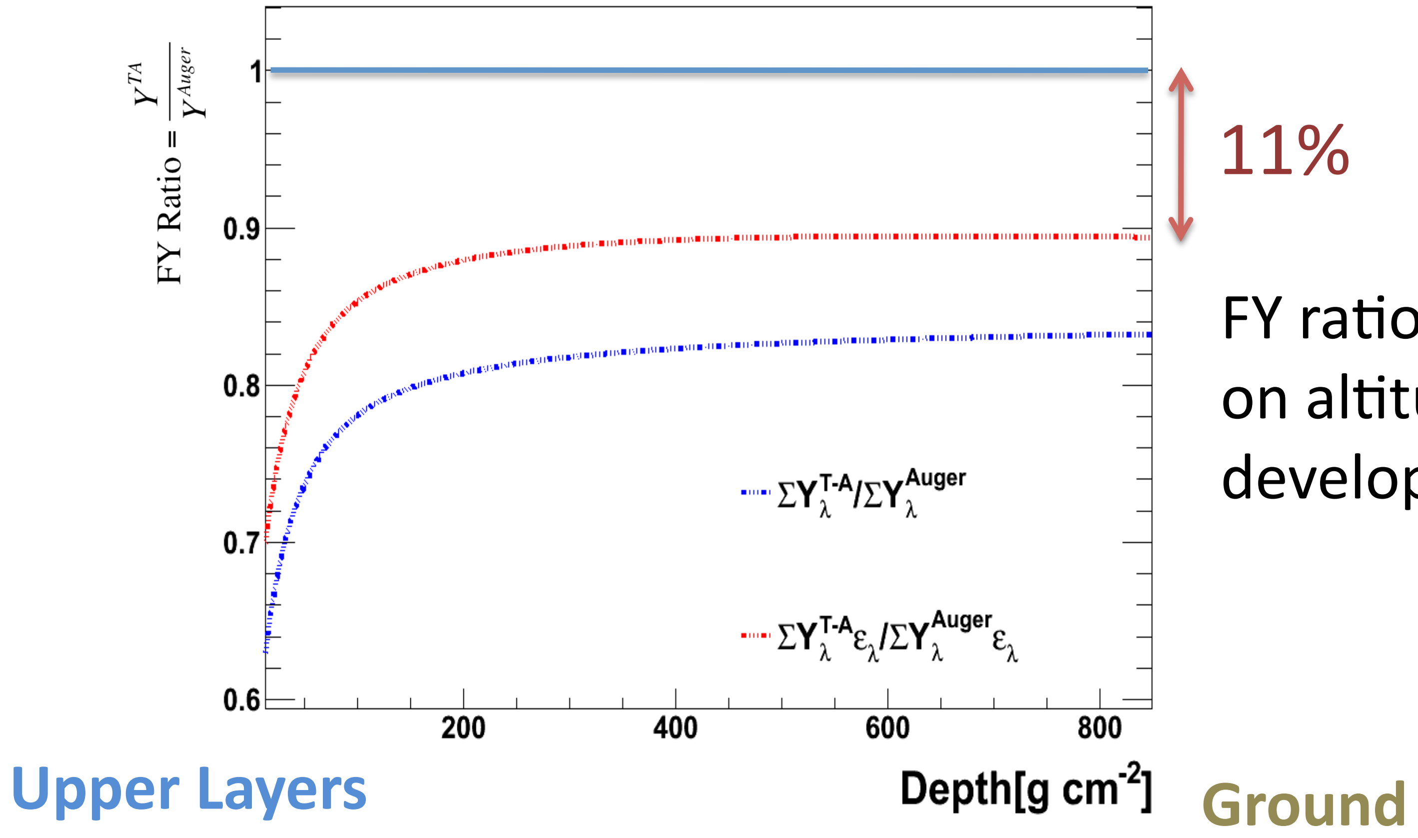
$$Y^{TA}/Y^{Auger} = 0.89$$

FY difference between TA and Auger still remains when optical efficiency is included

FY ratio vs Depth
Telescope Array vs Auger

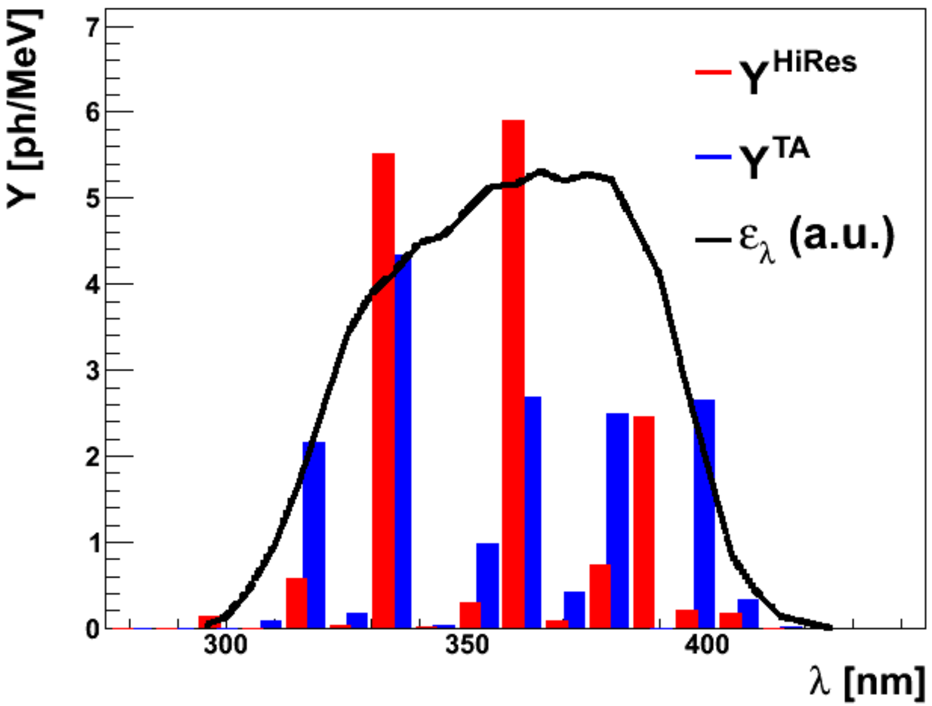
Y^{Auger} = fluorescence yield from the Auger dataset (no T,h)

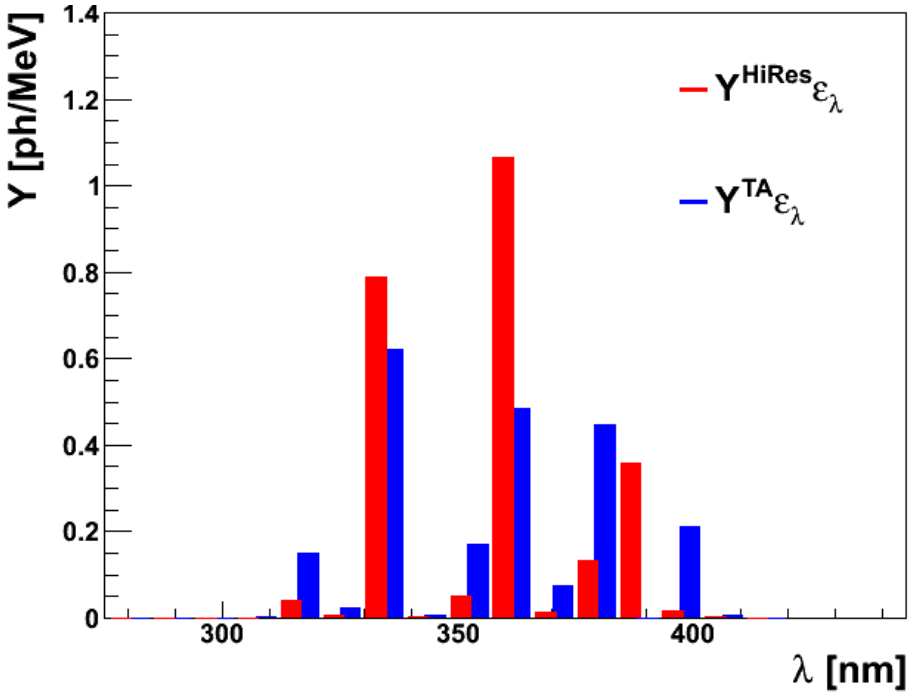
$Y^{T\text{-}A}$ = fluorescence yield from the Telescope Array dataset



FY ratio is independent on altitude in the shower development region

Comparison of FY: TA vs HiRes





Ratio of total yields

$$Y^{TA}/Y^{HiRes} = 1.02$$

Ratio including optical eficiency

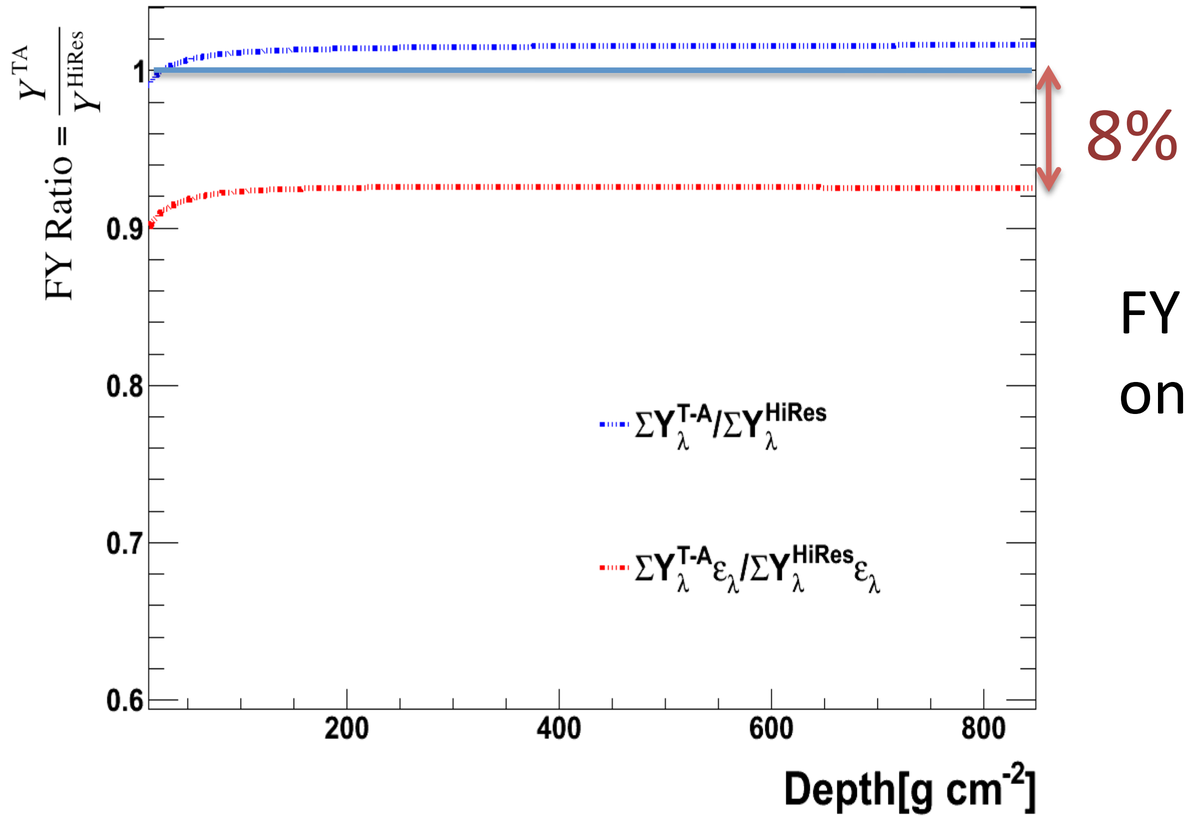
$$Y^{TA}/Y^{HiRes} = 0.92$$

Non-negligible discrepancies when optical efficiency is included

FY ratio vs Depth
Telescope Array vs HiRes

Y^{Auger} = fluorescence yield from the Auger dataset

$Y^{T\text{-}A}$ = fluorescence yield from the Telescope Array dataset



FY ratio is independent on altitude

Upper Layers

Ground

Data Sample

Hybrid data Pierre Auger Observatory

Atmospheric profiles: new Malargüe Monthly Models (Argentina)

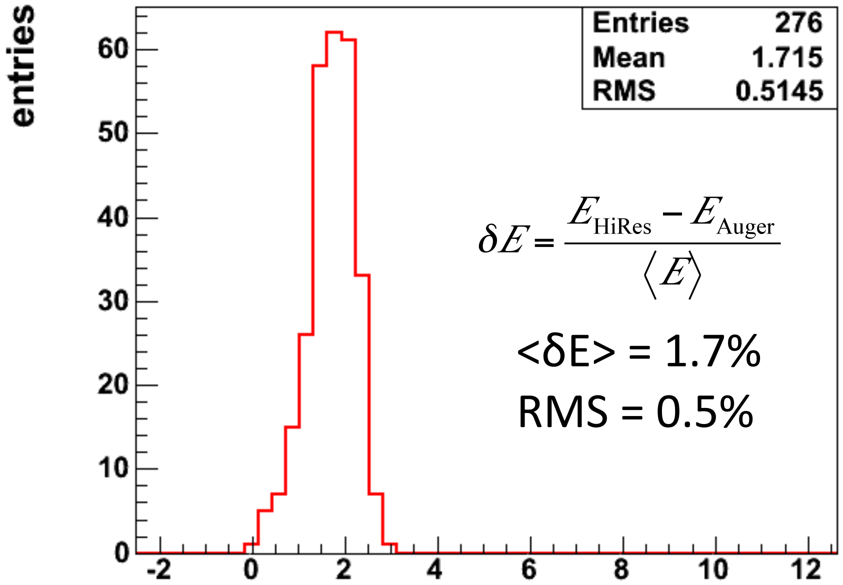
Software Offline with different **FY Dataset implemented**

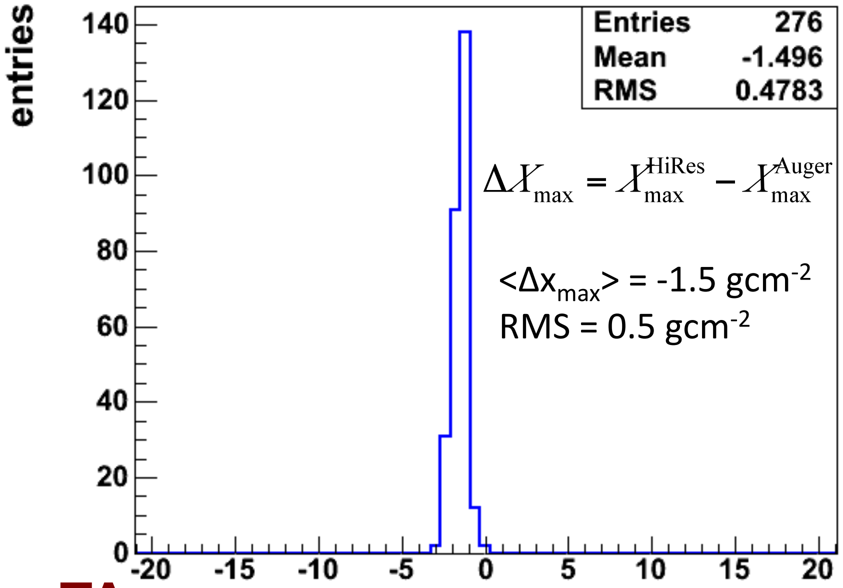
Cuts:

- ICRC 2007 Quality Cuts
- Xmax in FOV
- $\sigma\left(X_{\max}\right) < 40\ \mathrm{gcm}^{-2}$
- $\frac{\chi^2_{\mathrm{GH}}}{\mathrm{ndof}} < 2.5$
- $\frac{\sigma_E}{E} < 0.2$
- Distance to core r < 1500 m
- 5 pixels (at least) in axis fit
- Zenith angle < 60º
- logE > 18

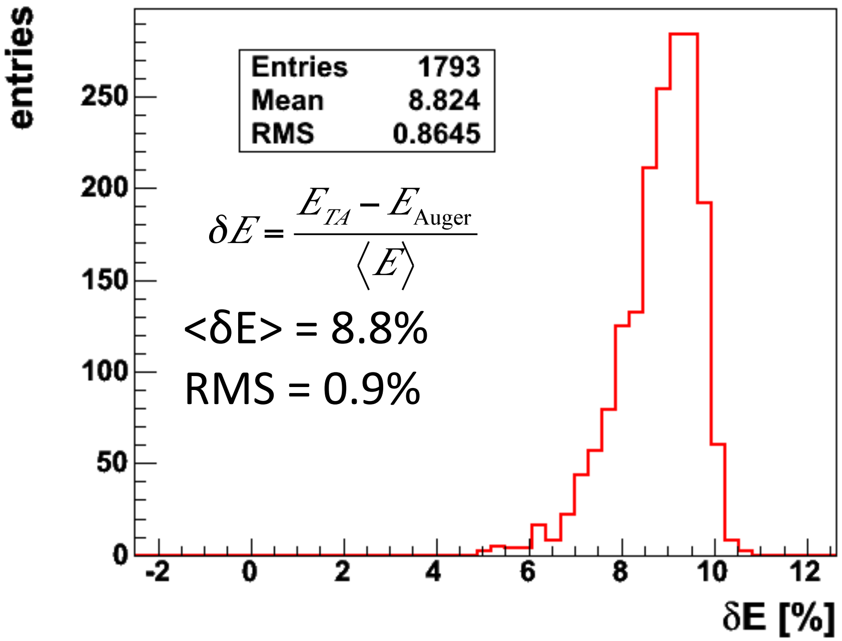
Shower parameters comparison:

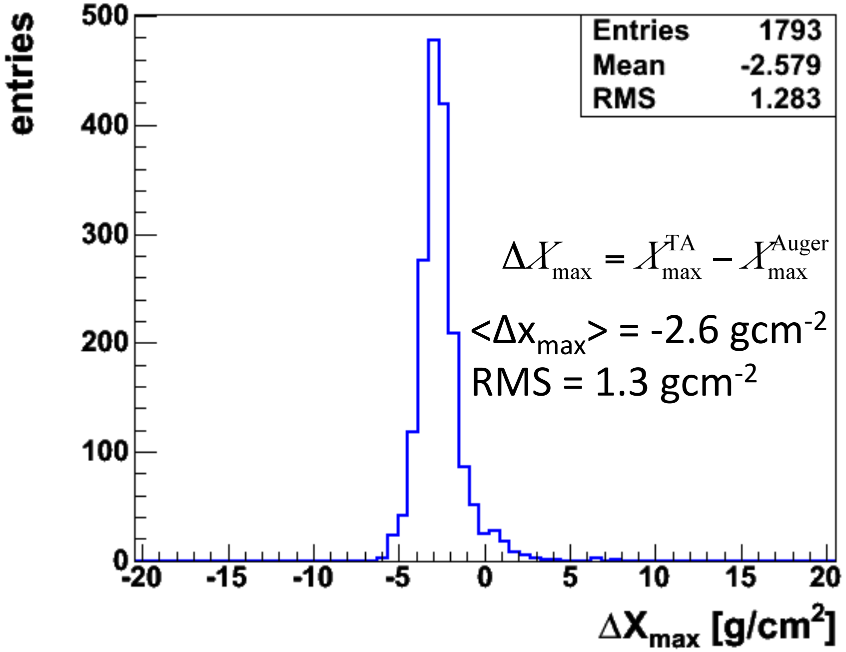
Auger vs HiRes





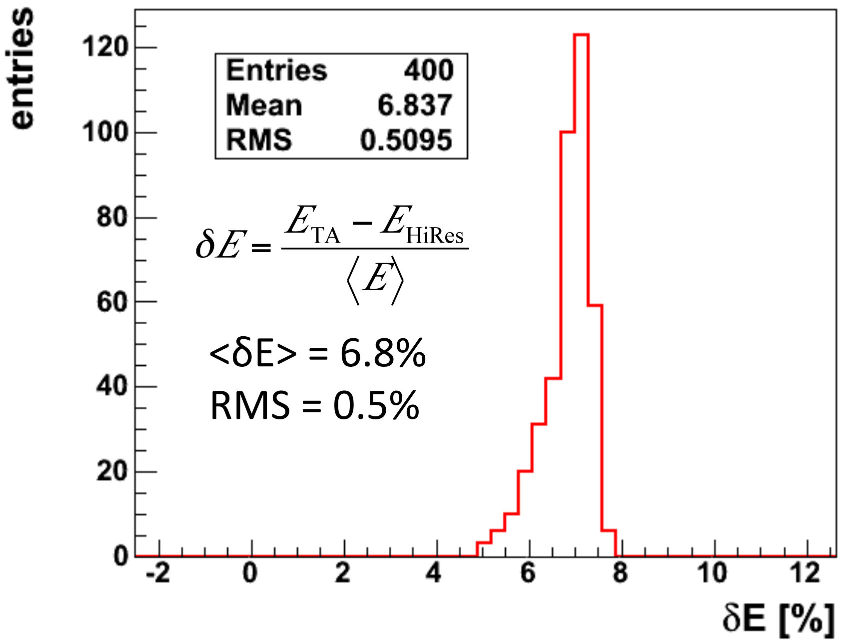
Auger vs TA

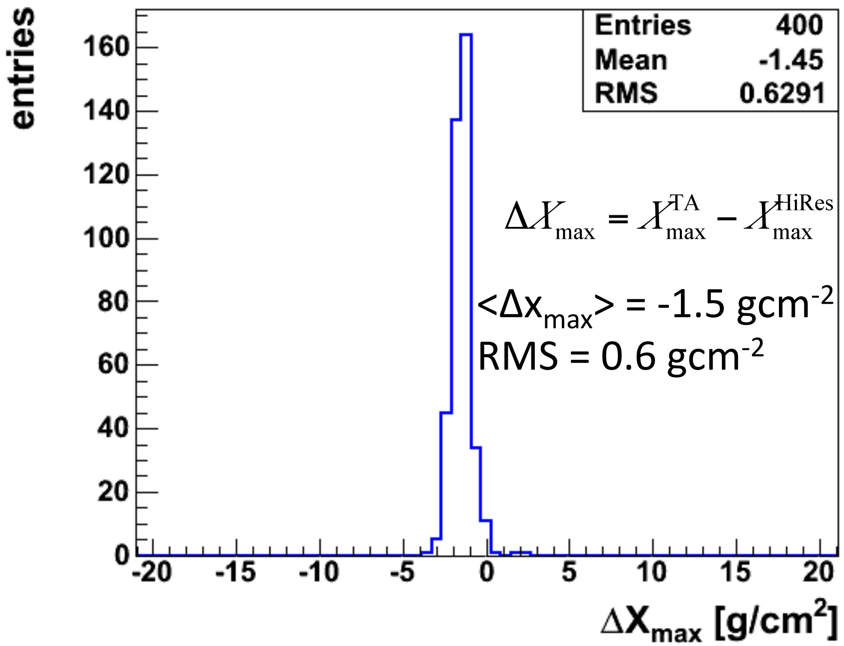




Shower parameters comparison:

HiRes vs TA





IMPACT OF QUENCHING UNCERTAINTIES (α and P'_W)

Quenching parameters Uncertainties

α, P'_w values measured by AIRFLY[1]:

λ (nm)	α_λ	p'_{H_2O} (hPa)
313.6	-0.09 ± 0.10	1.21 ± 0.13
337.1	-0.36 ± 0.08	1.28 ± 0.08
353.7	-0.21 ± 0.09	1.27 ± 0.12
391.4	-0.80 ± 0.09	0.33 ± 0.03

On average the uncertainties reported by AIRFLY

$$\sigma_T = \sigma(\alpha) \approx 0.25 \cdot \alpha \qquad \sigma_{P'_w} \approx 0.10 \cdot P'_w$$

Large uncertainties on parameters → ¿Reconstruction?

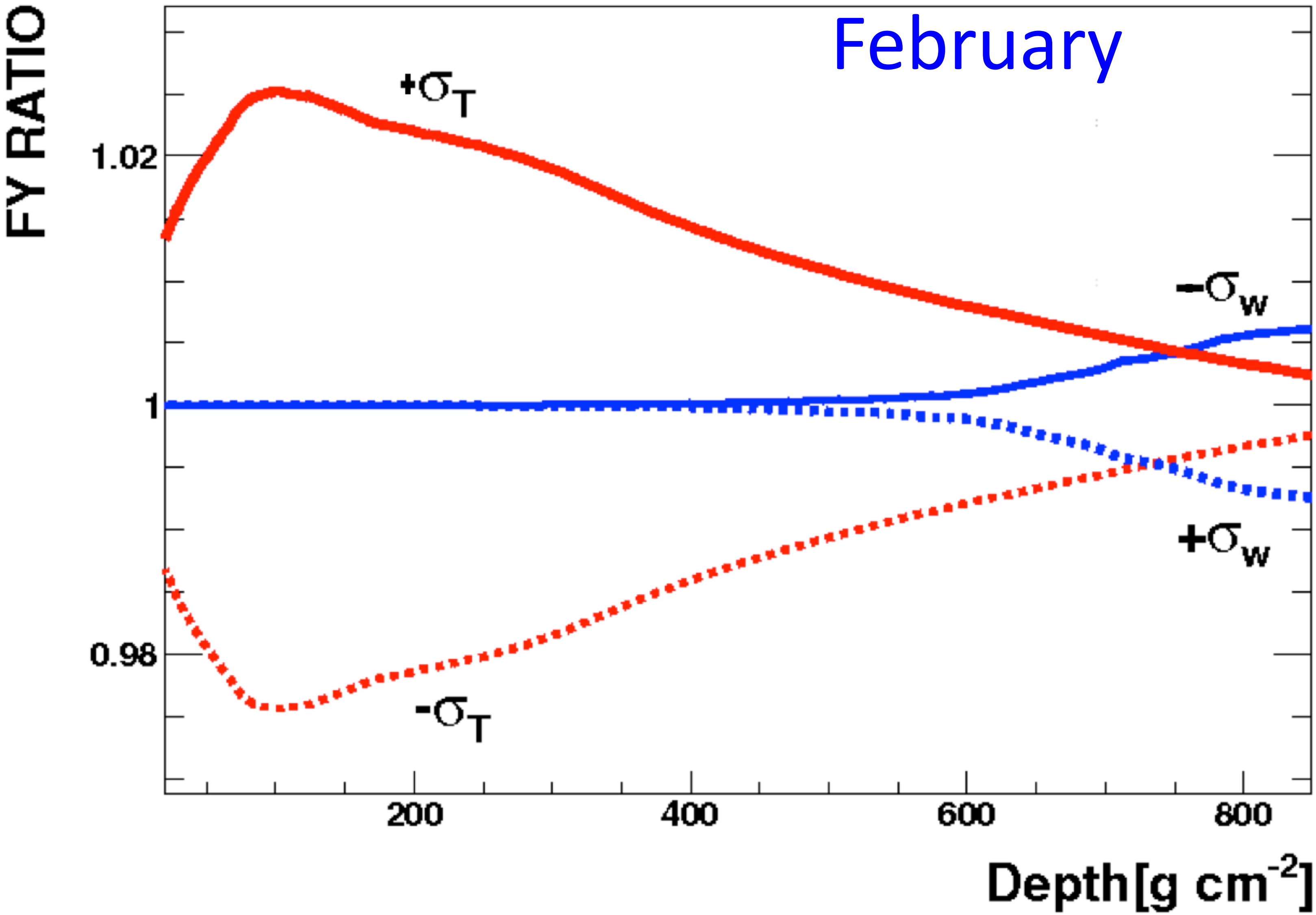
Changing Y_{auger} shifting:

α in ($\pm \sigma_T$) and P'_w in ($\pm \sigma_w$)

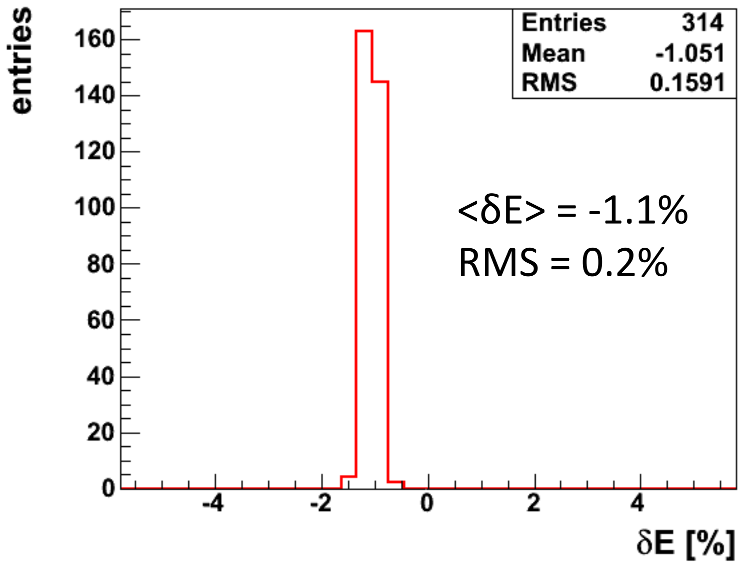
[1] NIM A **597** (2008) 50, updated by M. Bohacova (6th Fluorescence Air Workshop – L'Aquila)

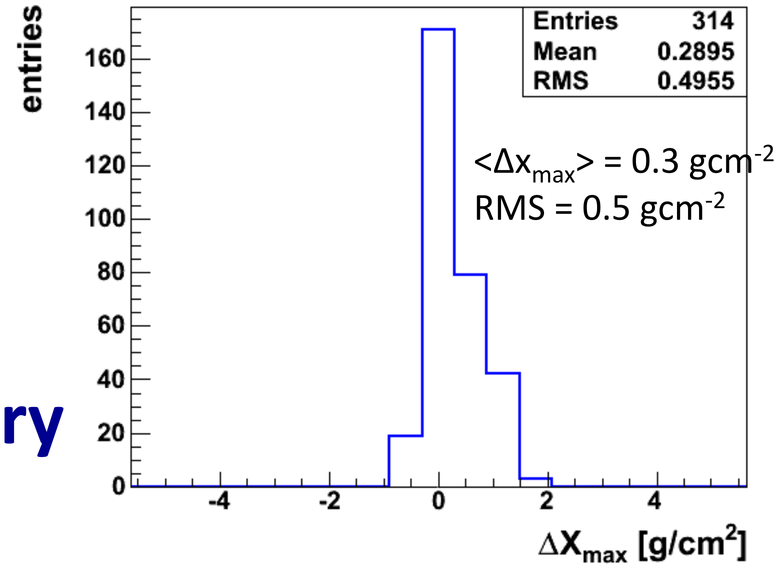
Quenching Parameters Uncertainties

$$\text{FY Ratio} = \frac{Y^{Modified}}{Y^{Auger+T+h}}$$



Uncertainties of P'_w and α on shower reconstruction



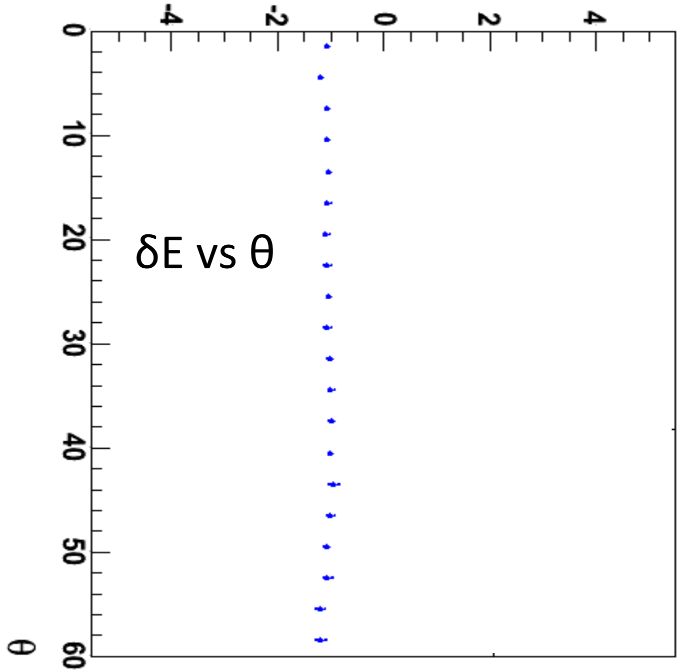


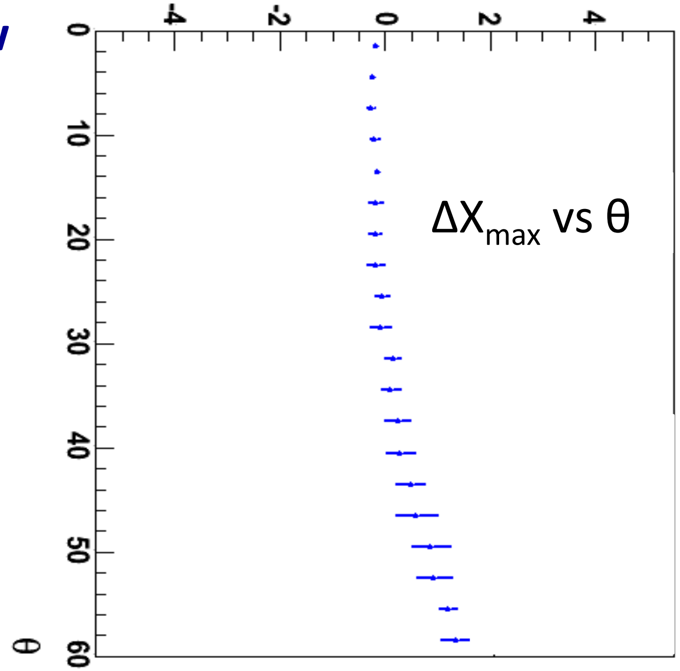
February

$\alpha + \sigma_T$

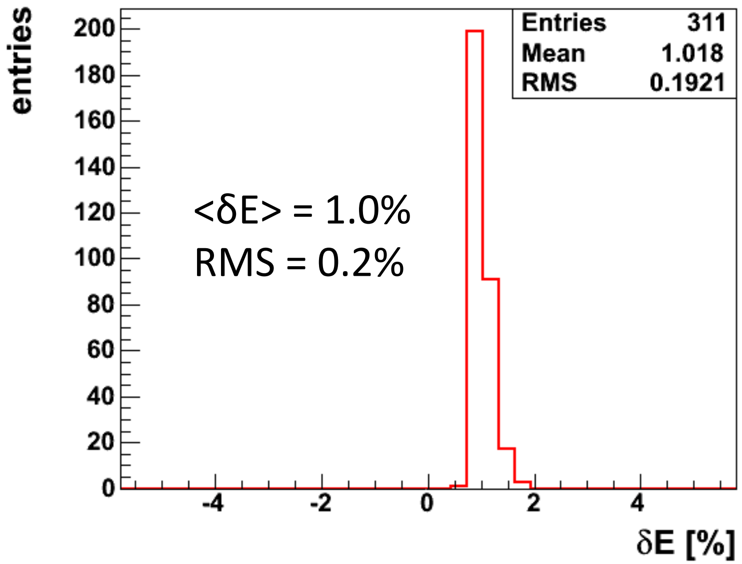
$P'_w - \sigma_w$

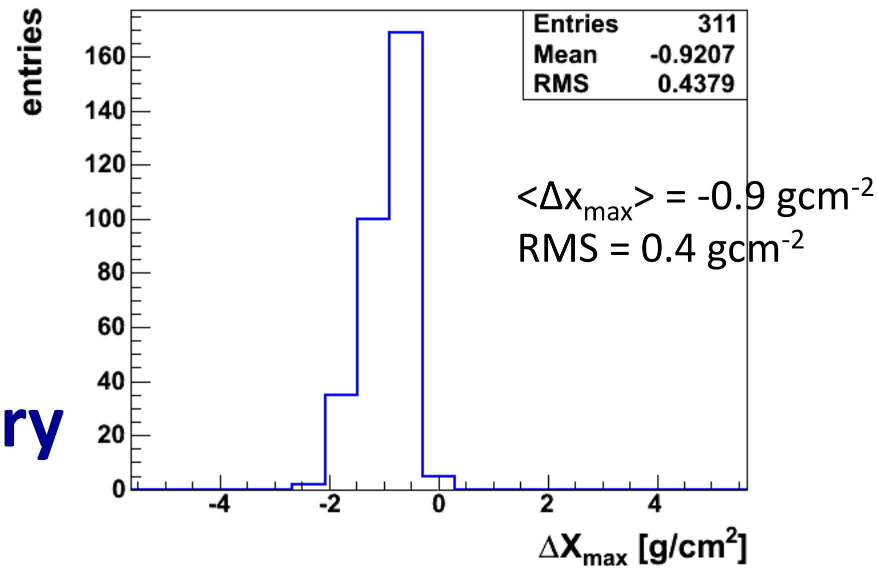
Y ↑





Uncertainties of P'_w and α on shower reconstruction



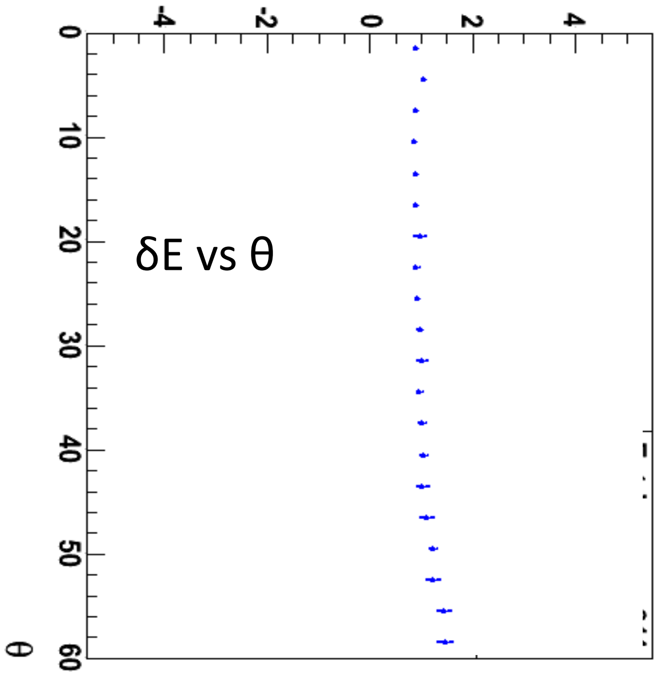


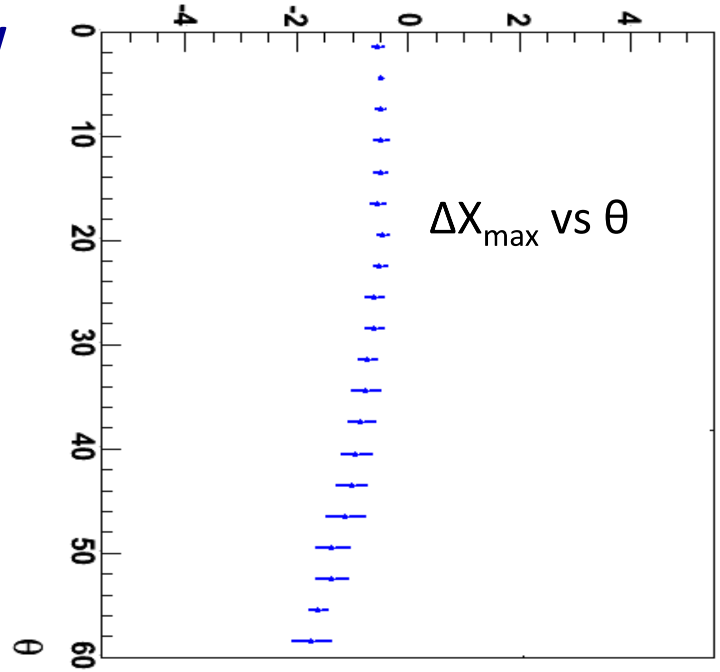
February

$\alpha - \sigma_T$

$P'_w + \sigma_w$

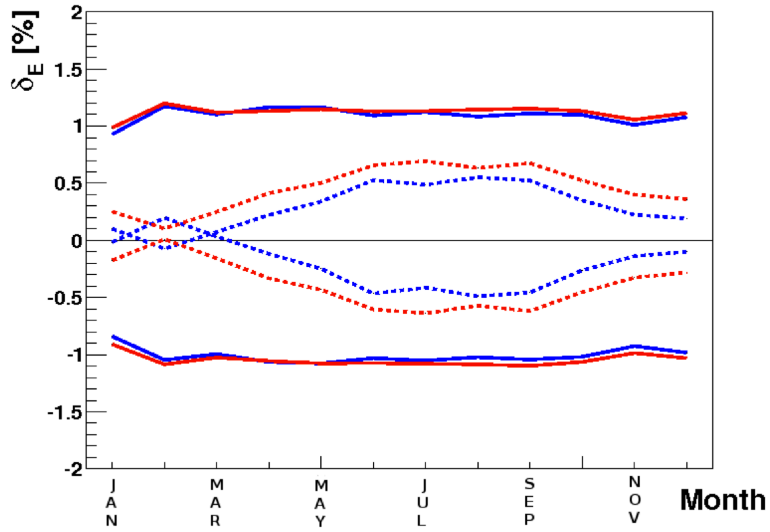
Y↓



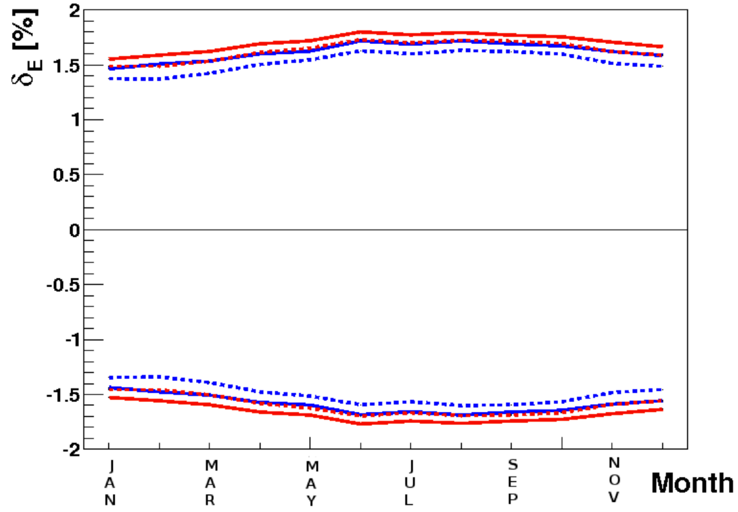


Uncertainties of P'_w and α on shower reconstruction

Results compatible with those obtained using a symple analytical method[1]



δE = 1.5% (30º)



δE = 1.5% (60º)

[1](Vázquez et al. ICRC 2011)

CONCLUSIONS

Conclusions

- The datasets currently employed by the different ultra-high energy cosmic rays experiments affect the reconstructed shower parameters, especially the energy

Auger vs HiRes: $\langle\delta E\rangle = 1.7\%$

Auger vs TA: $\langle\delta E\rangle = 8.8\%$

HiRes vs TA: $\langle\delta E\rangle = 6.8\%$

- An effort to employ the same datasets must be done in order to get rid of systematics uncertainties.

- Current uncertainties on quenching parameters translate to less than 1% to the reconstructed energy.