

# Update of the average value of available measurements of the absolute air-fluorescence yield

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# Outline

1. Introduction
2. Updates
3. Results

# 1. Introduction

## 1. Introduction

- FY (**ph/MeV**) results normalized to **337 nm**, **1013 hPa** and **293 K** (dry air) using fluorescence spectrum of AIRFLY\*

$$Y_{337}(P_0, T_0) = Y_{\Delta\lambda}(P, T) \frac{I_{337}}{I_{\Delta\lambda}} \frac{1 + P/P'(T)}{1 + P_0/P'(T_0)}$$

$$\underset{P \gg P'}{\approx} Y_{\Delta\lambda}(P, T) \frac{I_{337}}{I_{\Delta\lambda}} \frac{P}{P_0} \sqrt{\frac{T_0}{T}}$$

**independent of  $P'$**

\*M. Ave *et al.*, *Astropart. Phys.*, 28 (2007) 41

## 1. Introduction

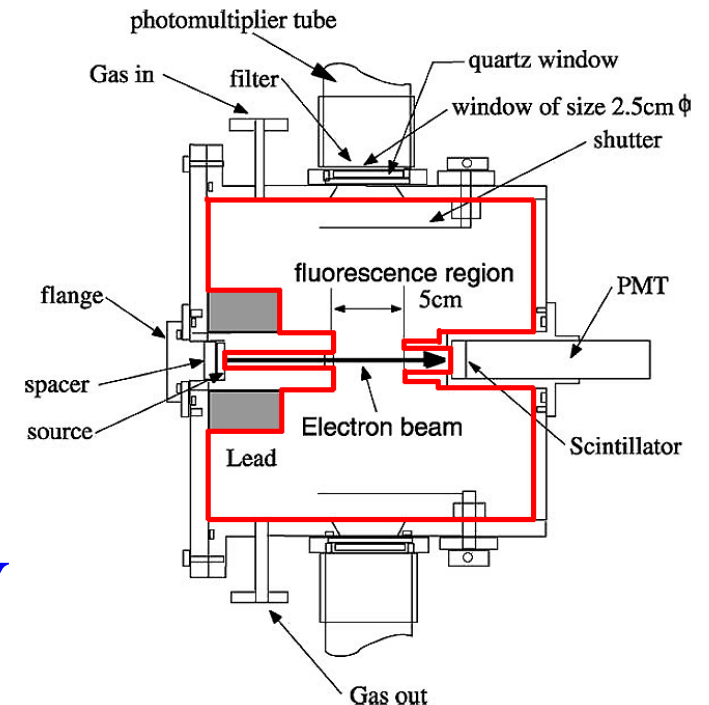
- Dedicated simulations of each experiment using our **MC algorithm**\* to calculate the **deposited energy** and some geometrical factors
  - Large corrections ( $>6\%$ ) for “type A” experiments using the Bethe-Bloch energy loss, i.e., ignoring secondaries (e.g., Nagano)
  - General agreement ( $\sim 2\%$ ) with simulations performed by “type B” experiments using GEANT4 or EGS4

\*Talk of F. Arqueros

## 1. Introduction

### Experiment of **Nagano *et al.***\* (used in Auger)

- Simulation including geometrical details
- Corrections:
  1. Total track length: -1%
  2. Geometrical acceptance: +1%
  3. Deposited energy: +6%
- **5.05 ph/MeV  $\rightarrow$  5.35 ph/MeV**



\*M. Nagano *et al.*, *Astropart. Phys.* 20 (2003) 293;  
M. Nagano *et al.*, *Astropart. Phys.* 22 (2004) 235

## 2. Updates

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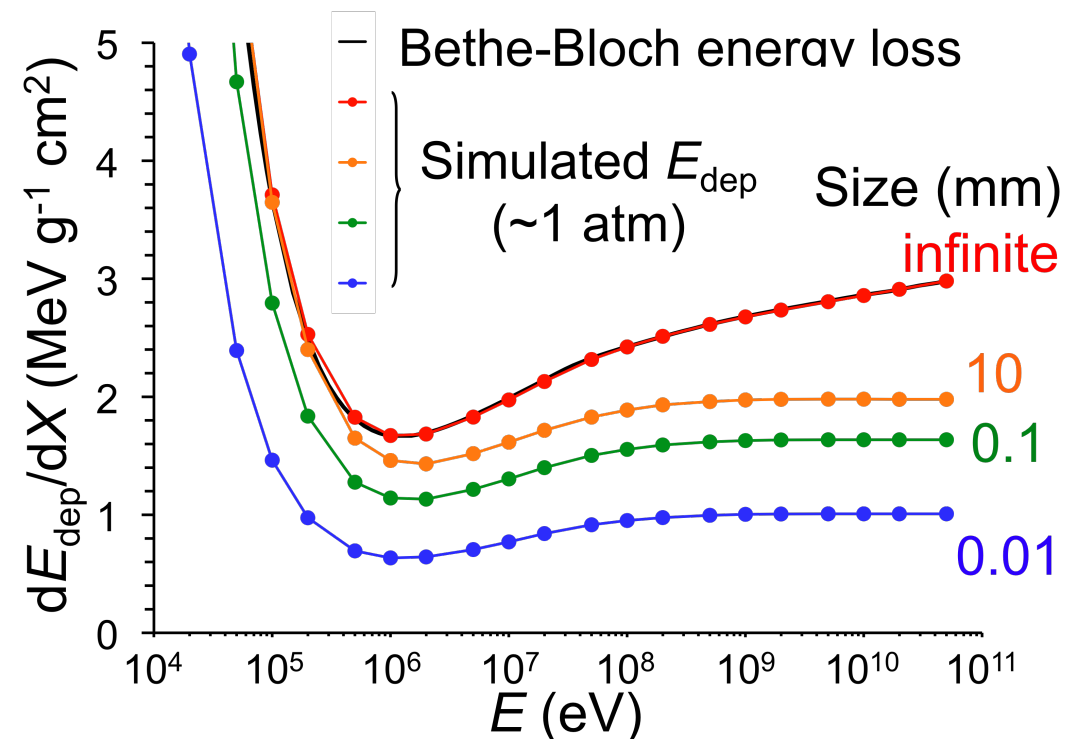
- Since our *Astropart. Phys.* 34 (2010) 134
  1. Improved MC algorithm
  2. Cross-check with GEANT4
  3. Statistical analysis and average
  4. New result of AIRFLY
- Our final analysis will be published soon (preliminary version already available at [arXiv:1103.2022](https://arxiv.org/abs/1103.2022))



## 2. Updates: Improved MC algorithm

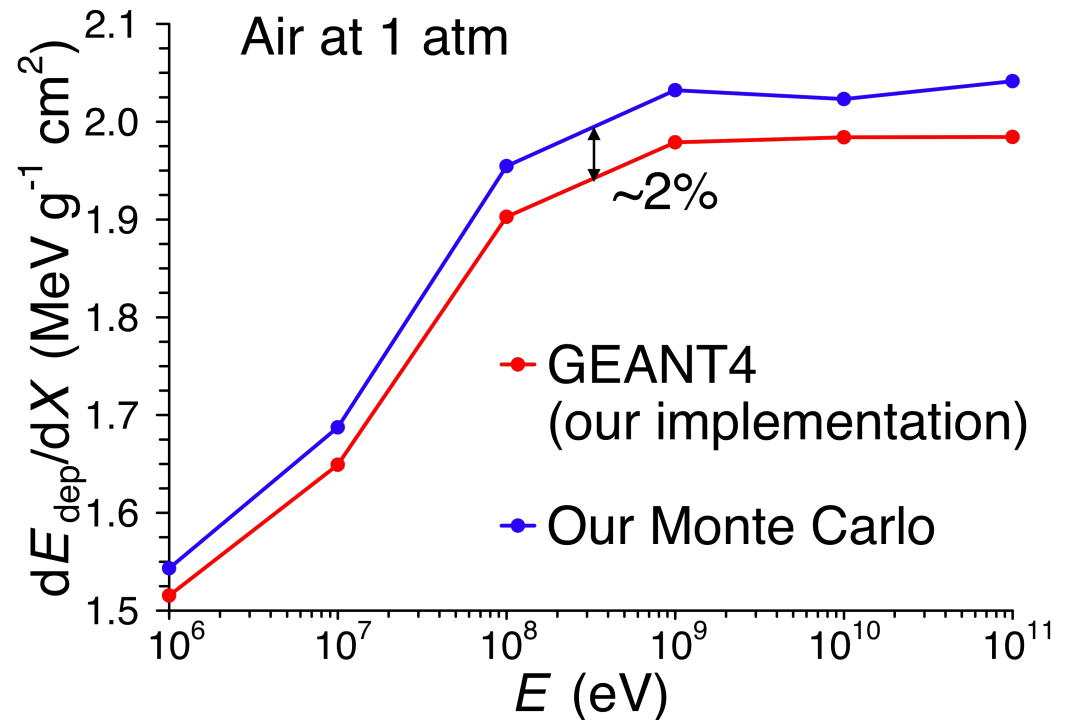
- **Density correction** applied to all cross sections (previously not applied to  $\sigma_K$ )

- Simulation better accounts for energy losses of electrons at **very high energy** ( $>10$  GeV)



## 2. Updates: Cross-check with GEANT4

- Simulations at **identical conditions**
- **Systematic difference of  $\sim 2\%$**   
(1 MeV – 100 GeV)



- Our GEANT4 results fully compatible with those of AIRFLY\* and MACFLY\*\*

\*Private communication

\*\*P. Colin *et al.*, *Astropart. Phys.* 27 (2007) 317

## 2. Updates: Statistical analysis

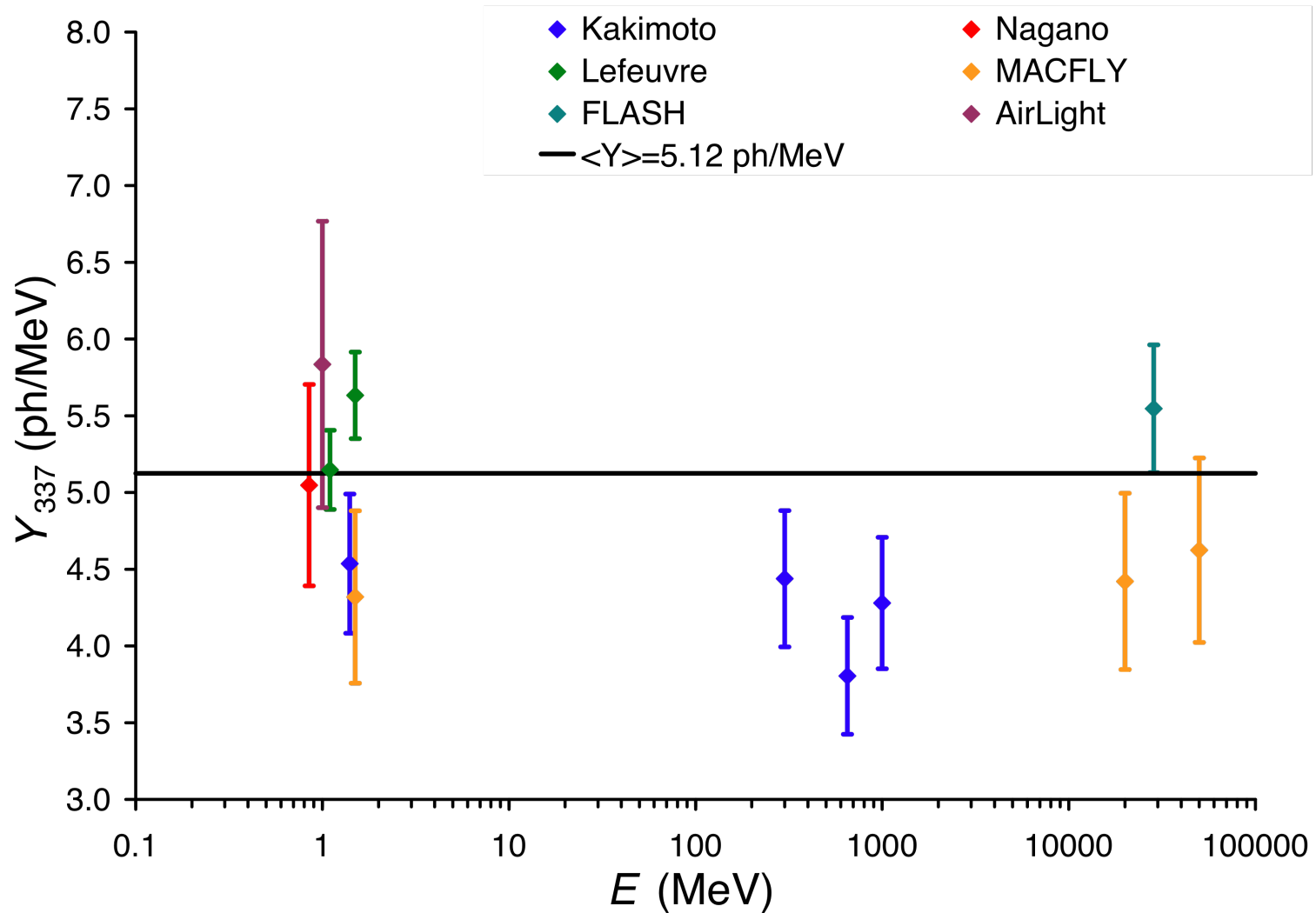
- Compatibility study ( $\chi^2$ ): outliers, weights...
- Effect of **corrections**
- Effect of very weak energy dependence of FY predicted by our MC algorithm
- New **result of AIRFLY\***:  
 $Y_{337} = 5.61 \text{ ph/MeV (4\%)} \text{ at } 1013 \text{ hPa, } 293 \text{ K}$
- **Average value** of the FY

\*Talk of M. Bohacova

# 3. Results

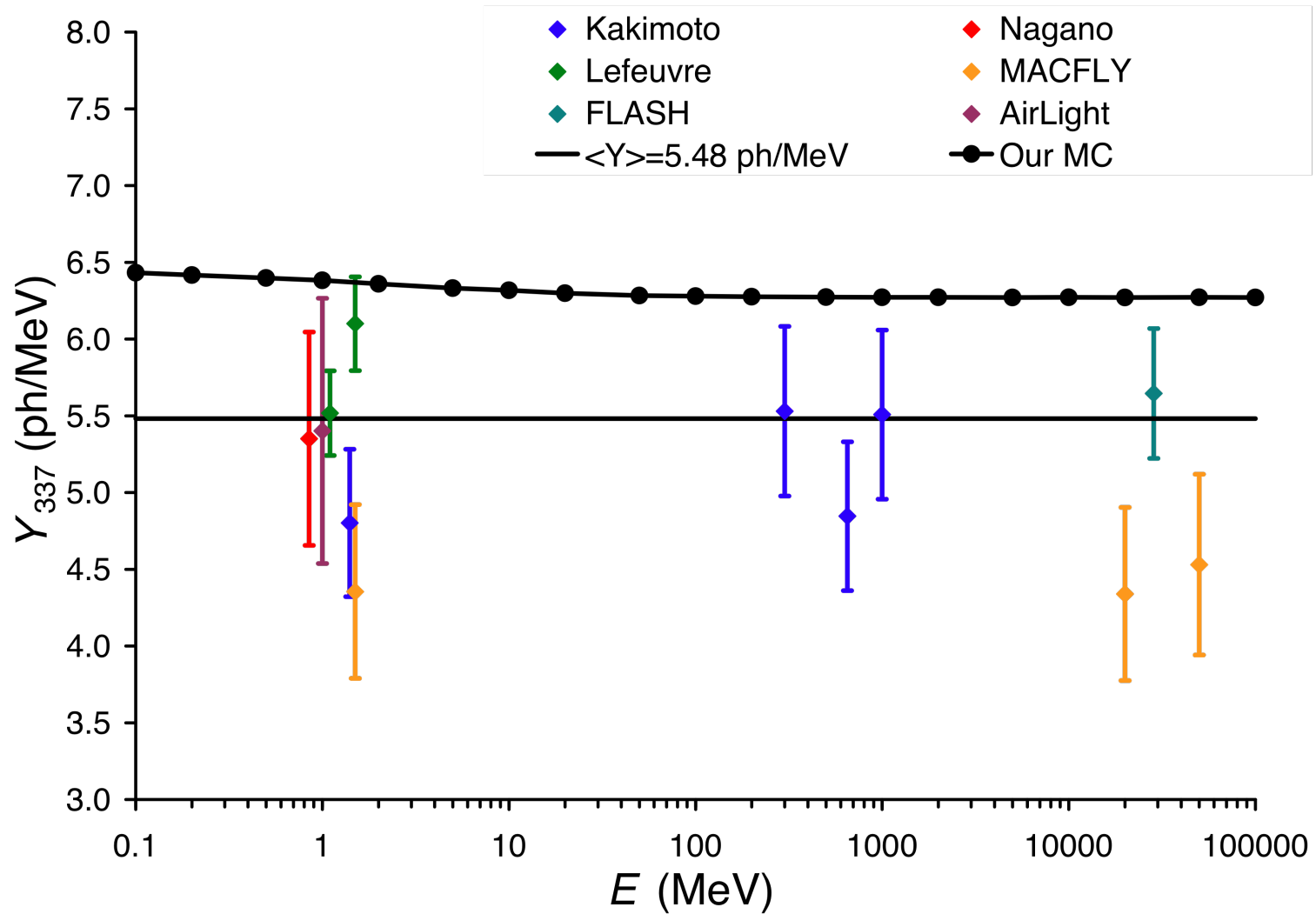
### 3. Results

## Normalized FYs **without corrections** vs energy



### 3. Results

## Normalized FYs **with corrections** vs energy



### 3. Results

- Statistical analysis

→ Different measurements of a same experiment are averaged assuming same systematic error

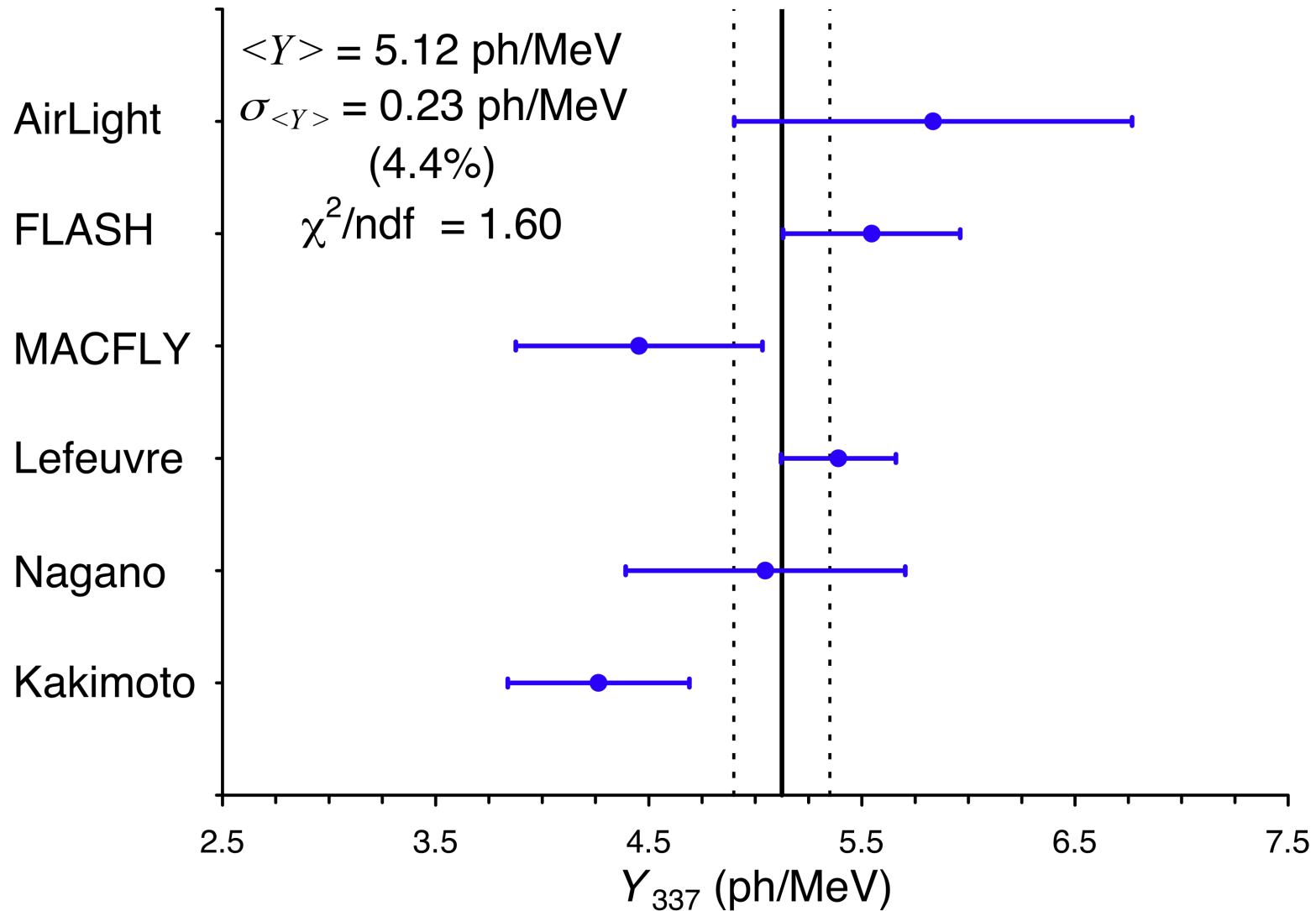
→ Weighted mean, variance and  $\chi^2$  statistic

$$\langle Y \rangle = \frac{\sum_i w_i Y_i}{\sum_i w_i}, \quad w_i = \frac{1}{\sigma_i^2}$$

$$\sigma_{\langle Y \rangle}^2 = \frac{\chi^2 / \text{ndf}}{\sum_i 1 / \sigma_i^2}, \quad \chi^2 / \text{ndf} = \frac{1}{n - 1} \sum_i \frac{(Y_i - \langle Y \rangle)^2}{\sigma_i^2}$$

### 3. Results: Statistical analysis prior to AIRFLY

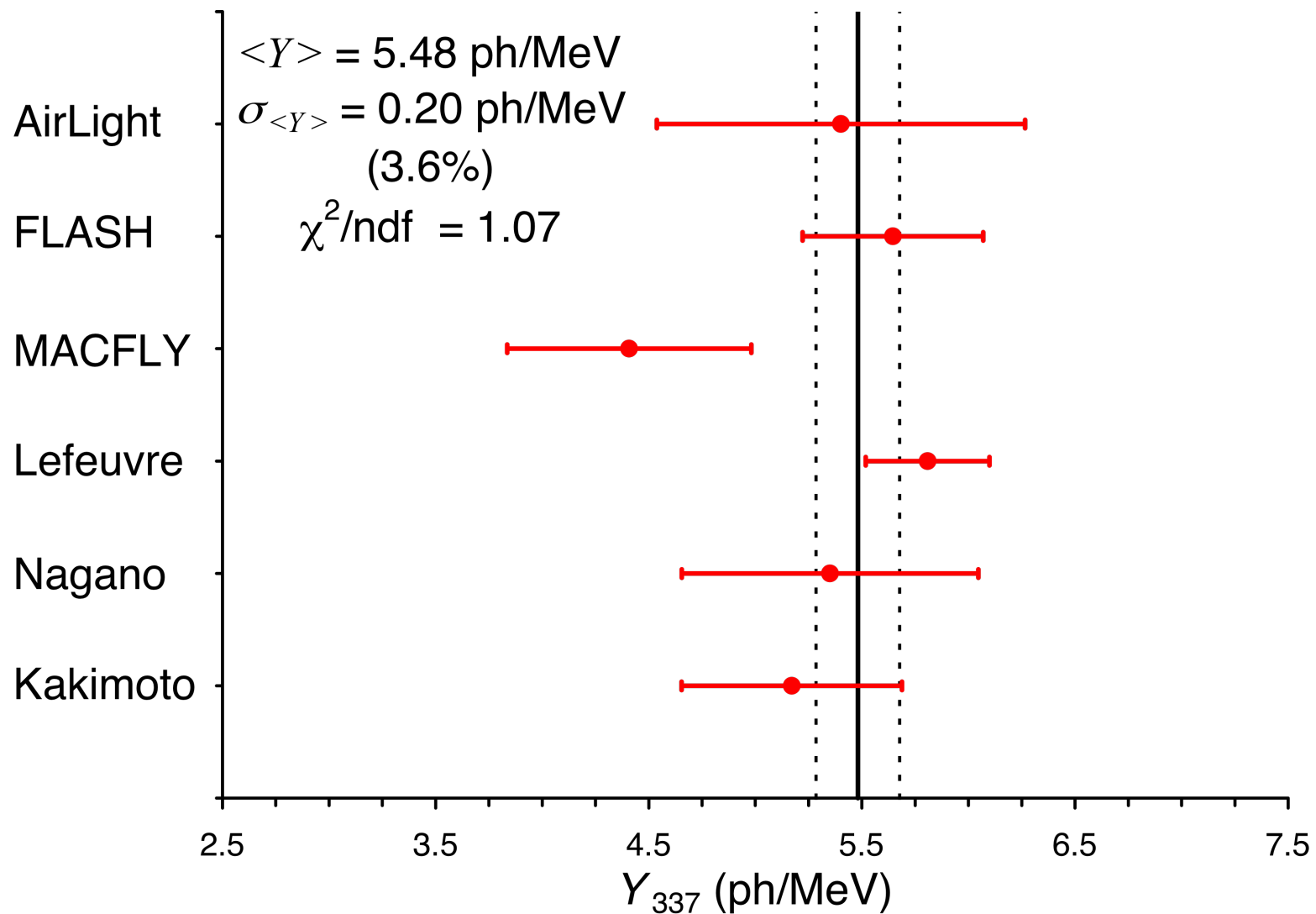
## Uncorrected sample





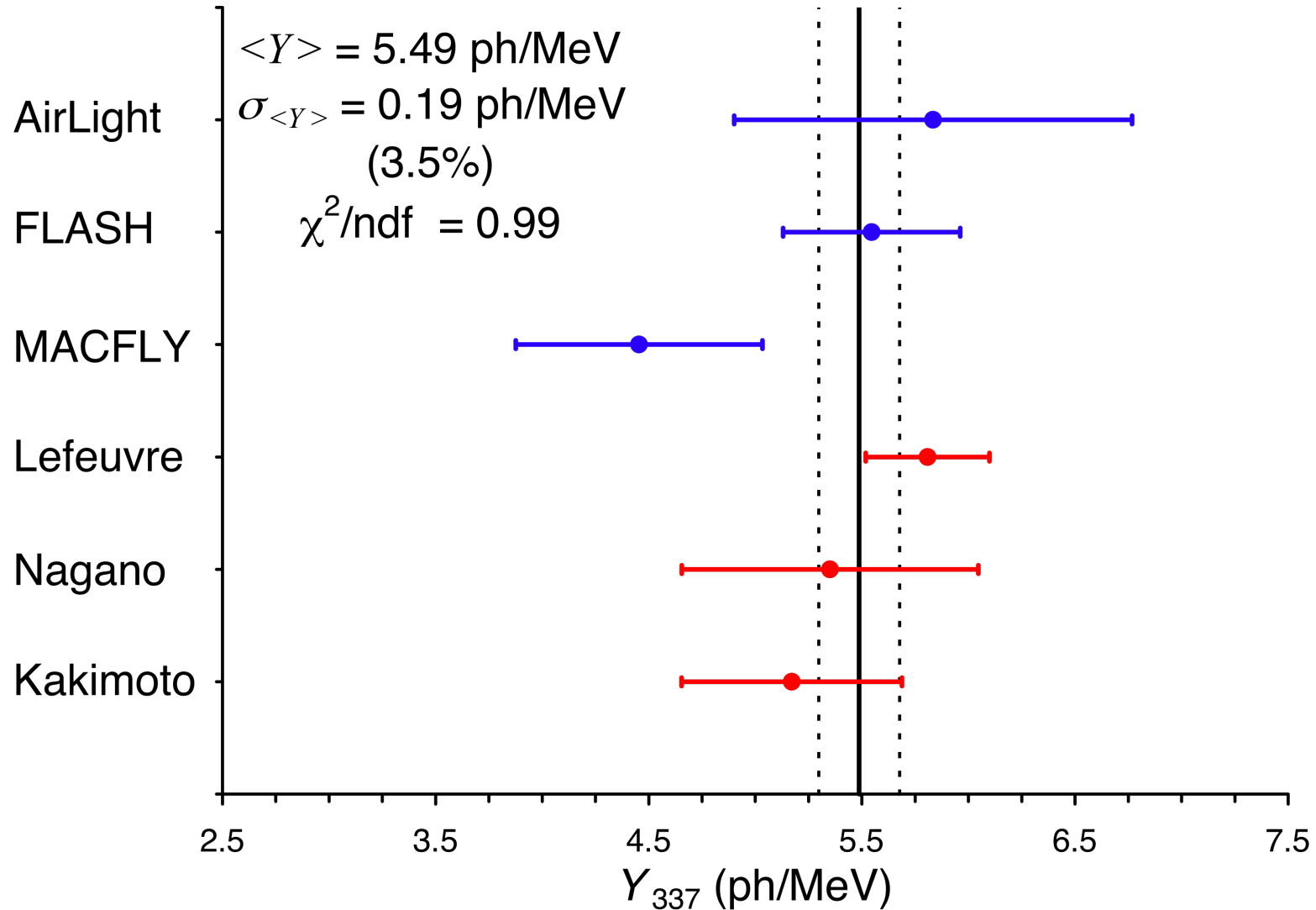
### 3. Results: Statistical analysis prior to AIRFLY

## Corrected sample



### 3. Results: Statistical analysis prior to AIRFLY

## No corrections to “type B” experiments



### 3. Results: Statistical analysis prior to AIRFLY

Test	$\langle Y \rangle$ (ph/MeV)	$\sigma$ (%)	$\chi^2/\text{ndf}$
Corrections	5.48	3.6	1.07
No corr. to type B exp.	5.49	3.5	0.99
No weights	5.30	3.8	-
Weak $E$ dependence	5.43	3.5	1.00
Excluding MACFLY	5.61	2.4	0.46
Excluding Lefeuvre	5.23	4.8	1.01

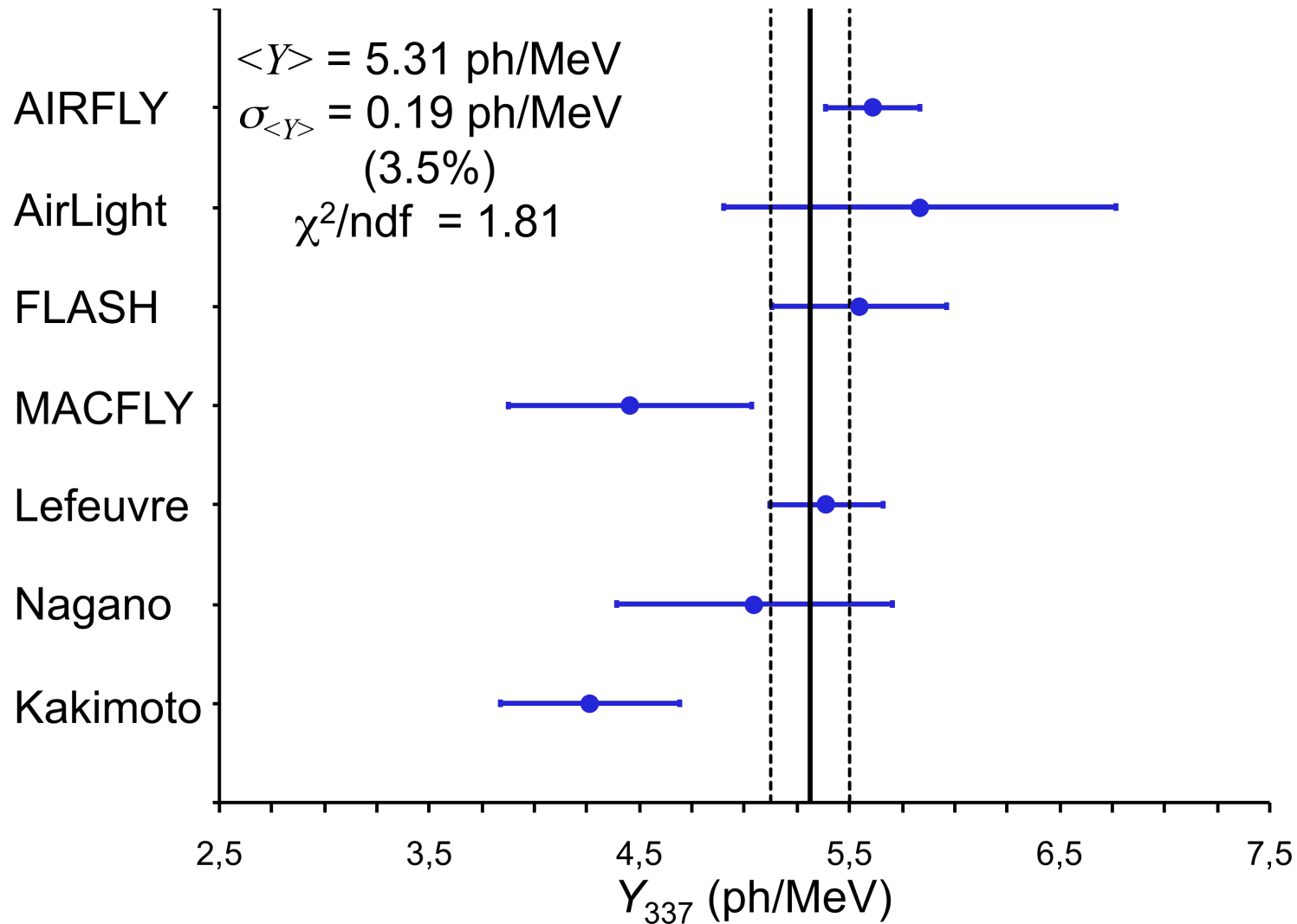
$\langle Y_{337} \rangle = 5.45 \text{ ph/MeV}$  with a conservative uncertainty of 5%

### 3. Results: Statistical analysis prior to AIRFLY

- **Compatibility** ( $\chi^2$ ) of results **improves** when corrections to “type A” experiments are applied
- From measurements prior to AIRFLY, we obtain  **$\langle Y_{337} \rangle = 5.45 \text{ ph/MeV (5\%)}$**
- Good agreement (3%) with the AIRFLY result of  **$Y_{337} = 5.61 \text{ ph/MeV (4\%)}$**
- Difference is even smaller taking into account the systematic **2% difference** between **GEANT4** and our MC

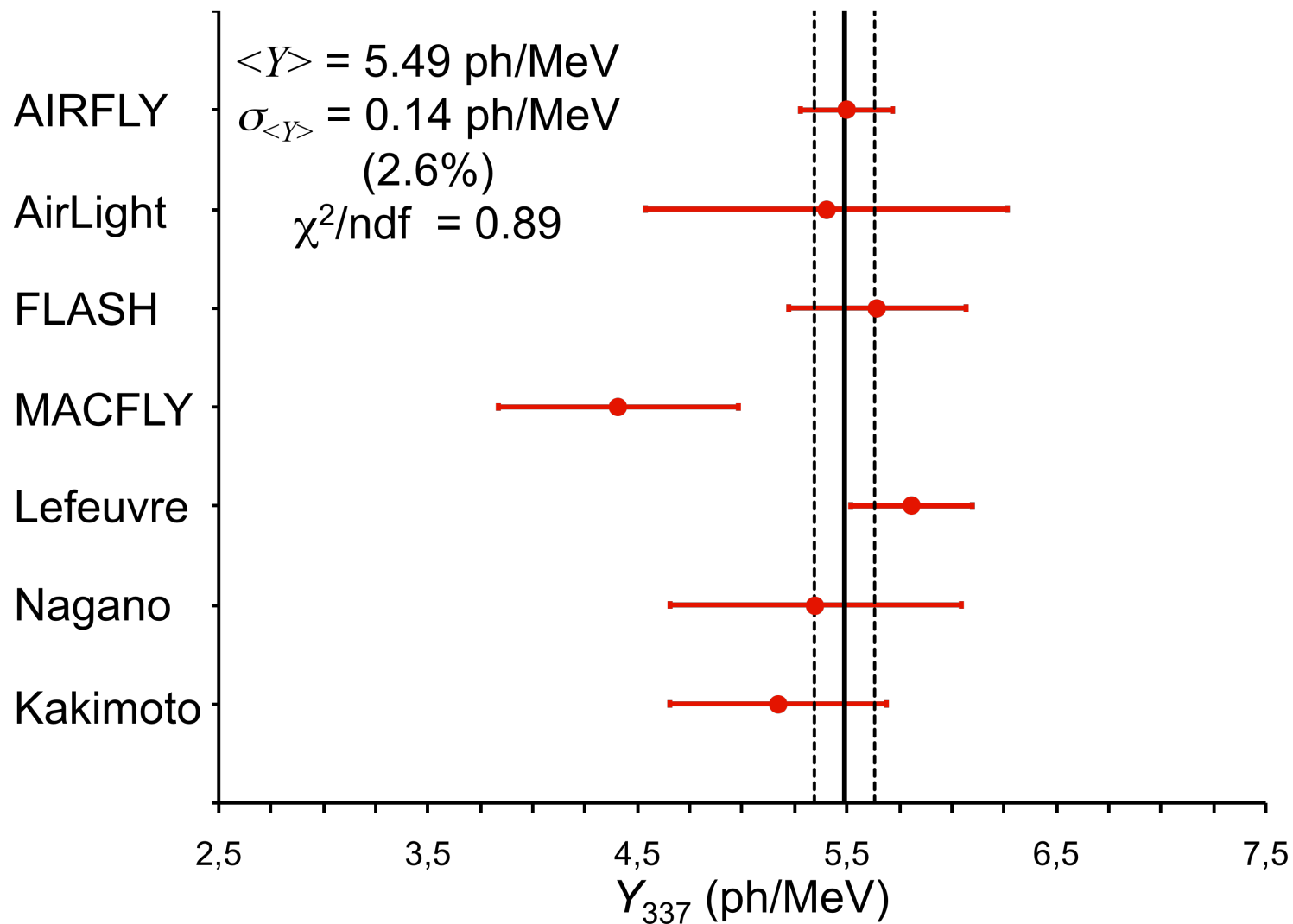
### 3. Results: Statistical analysis with AIRFLY

## Uncorrected sample



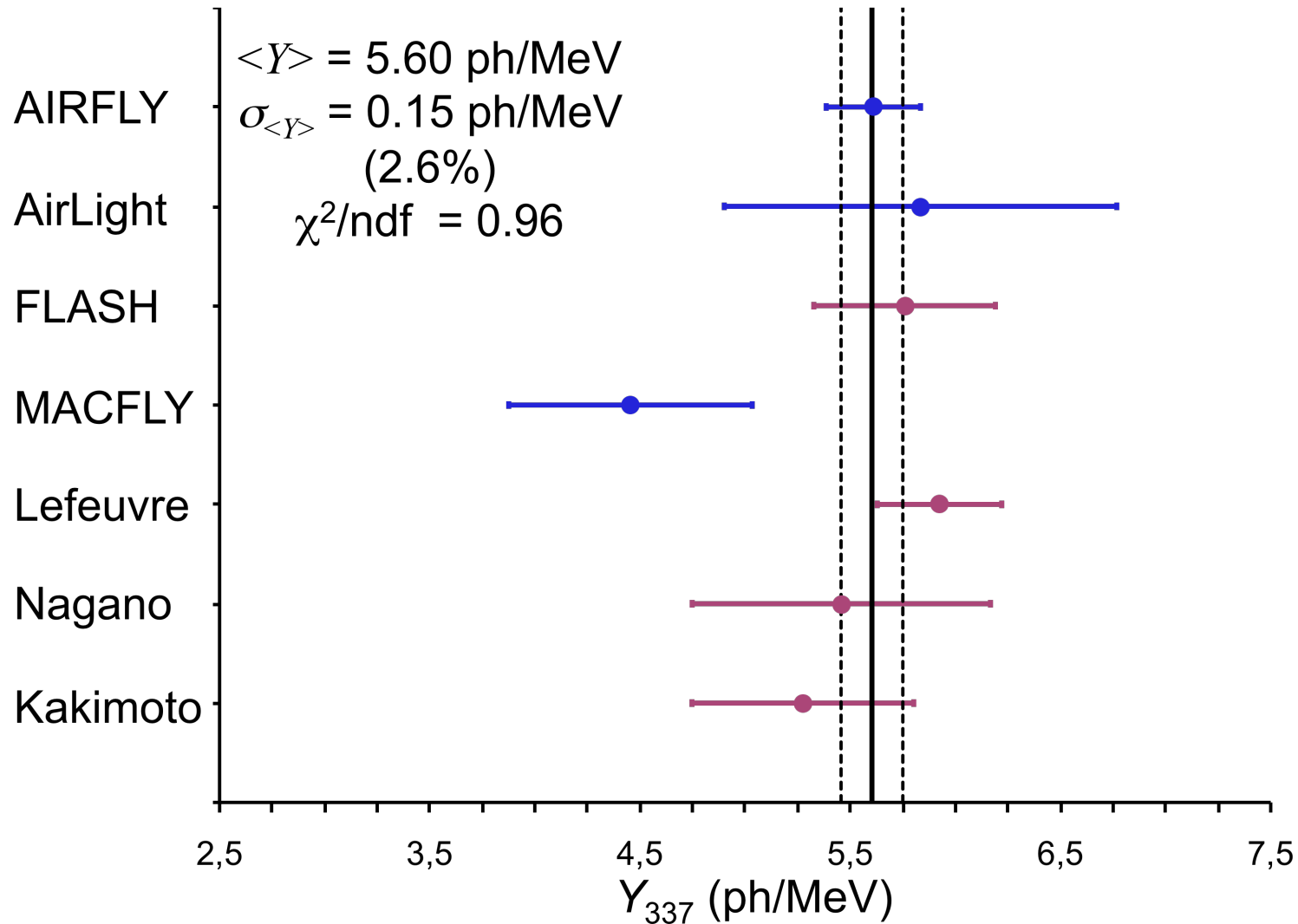
### 3. Results: Statistical analysis with AIRFLY

## Consistent with our MC



### 3. Results: Statistical analysis with AIRFLY

## Consistent with GEANT4



### 3. Results: Conclusions

- **Compatibility** of results even **improves** when the AIRFLY result is included
- We obtain  $\langle Y_{337} \rangle = 5.49 \text{ ph/MeV (3\%)}$  consistent with our MC algorithm
- We obtain  $\langle Y_{337} \rangle = 5.60 \text{ ph/MeV (3\%)}$  consistent with GEANT4
- Systematic **difference of 2%**
- An intermediate value:  
 $\langle Y_{337} \rangle = 5.55 \text{ ph/MeV (4\%)} ?$



# Thanks!