Preliminary: for the Spectrum Skype Meeting of 4th March 2009

SD calibration: ICRC 2009(?)

- Data Sample
- Event Selection
- CIC
- Resolutions
- Calibration Curve Procedure
- Systematics

C. Di Giulio

Data Sample

Hybrid events in the Hybrid Spectrum Paper Web Page:

-) 2004-2008

-) Reconstruction as in PRL Spectrum Paper.

-) New DB.

Events Selection Criteria

SD:

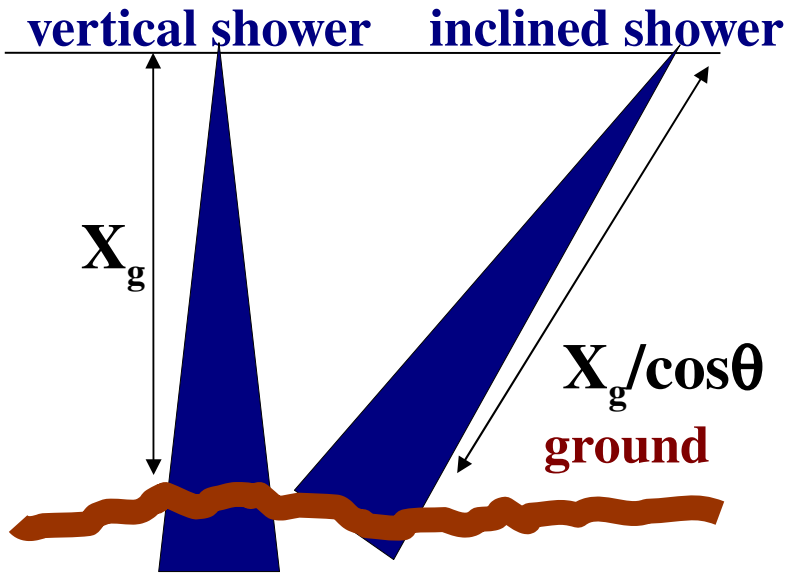
- SD T5 trigger
- Zenith < 60°.
- Bad Periods

as in PRL Spectrum Paper.

FD:

- Distance axis to tank < 750 m.
- X_{max} in FOV.
- Hole in the profile < 20%.
- Cherenkov fraction < 50%.
- $\chi^2_{(GH)}$/n.d.f. < 2.5.
- $\Delta E_{FD}/E_{FD}$ <20 % .
- XmaxErr.<40 g/cm^2
- Mie DB requested.
- No Loma Amarilla Data
- FD DB calib. period.
- Lin-GHChi2<4

C.I.C.



for each shower determine

$$S_{38} = \frac{S_{1000}}{1 + ax + bx^2} \quad x = \cos^2(\theta) - \cos^2(38°)$$

Intensity: 330

corresp to S38: 47.2862

a = 0.904545 +/- 0.0500676

b = -1.27621 +/- 0.228688

S_{38#circ}= 47.2862 +/- 0.763902

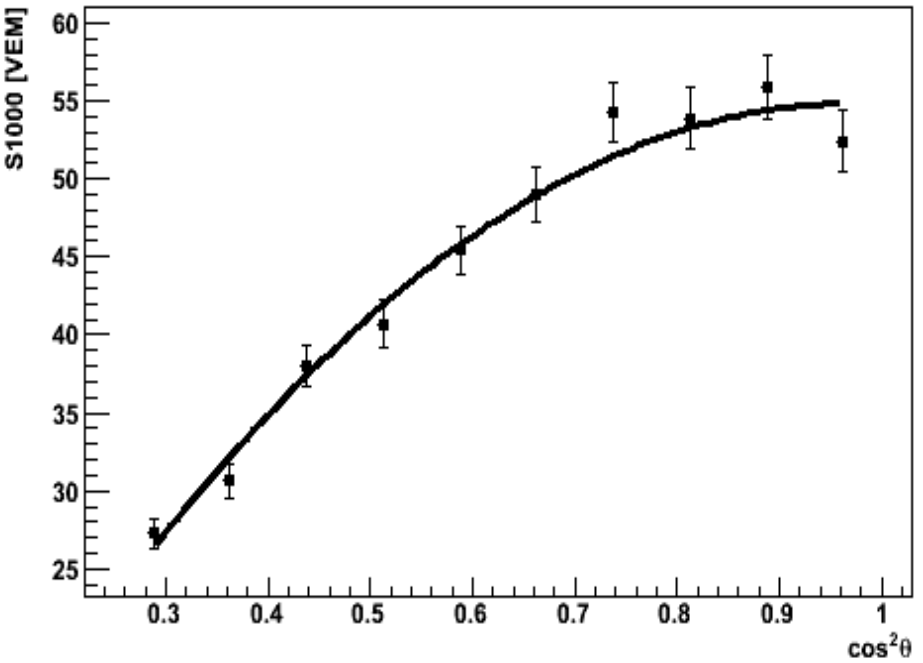
ab corr= 0.006348485

PRL a = 0.92 b = -1.13 I=330

Due to the attenuation in the atmosphere for the same energy and mass

S(1000;vertical)< S(1000;θ)

Attenuation curve derived with constant intensity cut technique.



S38, represents the signal at 1000m the very same shower would have produced if it had arrived from a zenith angle of 38°

S_{38° and E_{FD} uncertainties

- **Uncertainties on E_{FD}:**

$$\sigma^2_{E_{FD}} = \sigma^2_{GH-Fit} + \sigma^2_{Geom.} + \sigma^2_{Inv.Energy} + \sigma^2_{VAOD}$$

- **Uncertainties on S_{38°:**

$$\sigma^2_{S_{38^\circ}} = \sigma^2_{S_{38^\circ}}(CIC) + \sigma^2(\cos\vartheta) + \sigma^2(S_{1000})$$

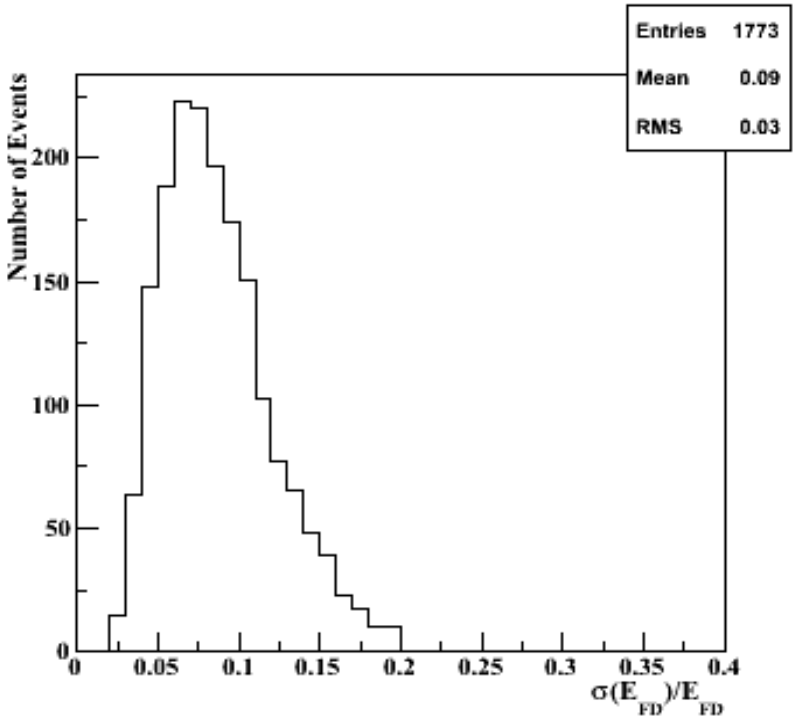
(σ_a, σ_b) (σ_ϑ) $(\sigma_{S_{1000}})$

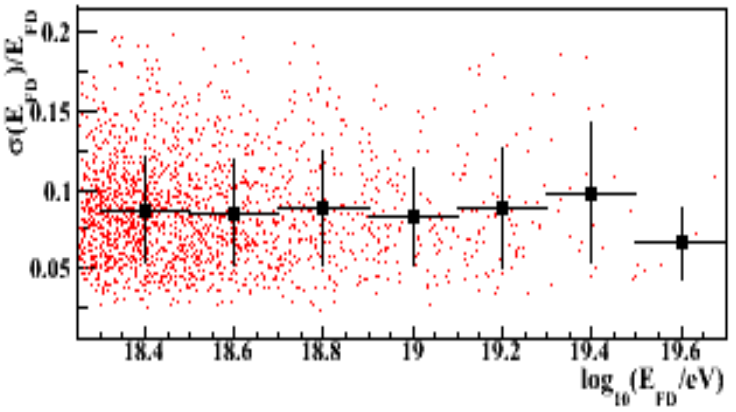
$$S_{38} = \frac{S_{1000}}{1 + ax + bx^2} \qquad x = \cos^2(\theta) - \cos^2(38^\circ)$$

$$\sigma^2(S_{1000}) = \sigma^2_{Shower-Fluctuation} + \sigma^2_{(LDF-Fit)} + \sigma^2_{\beta_{sys}}$$

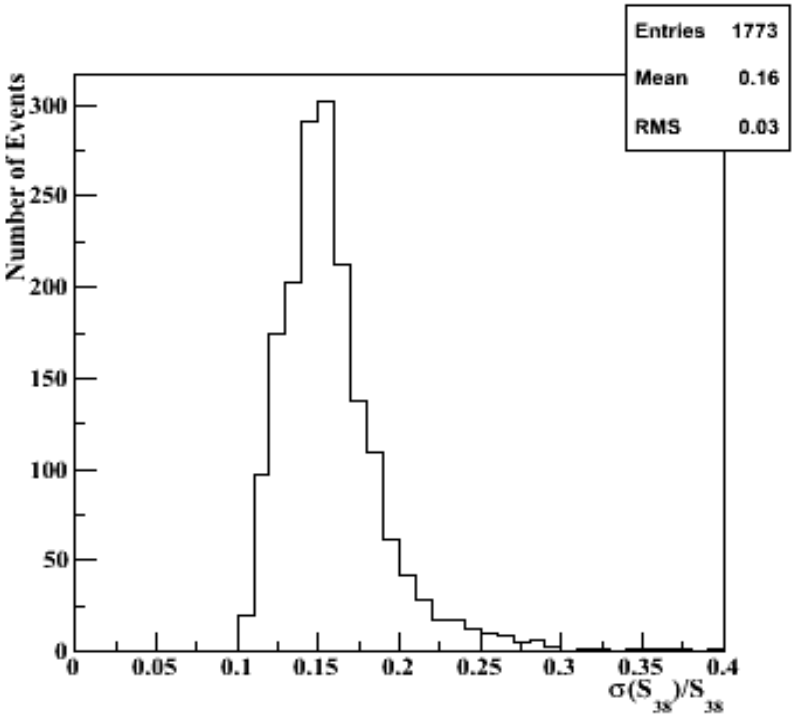
S_{38° and E_{FD} uncertainties

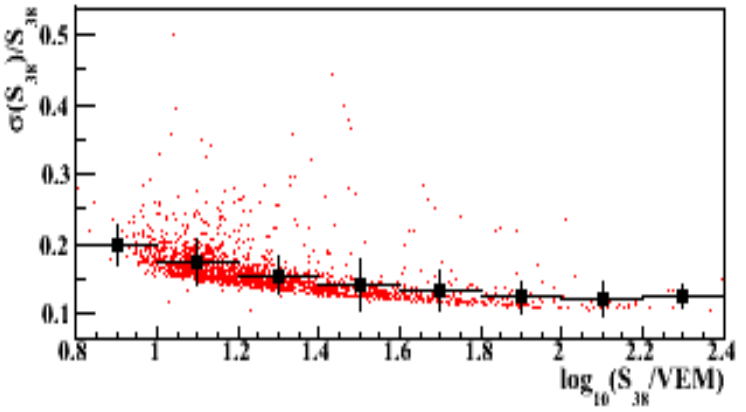
- **Uncertainties on E_{FD}:**





- **Uncertainties on S_{38°:**





SD Calibration using FD Energy

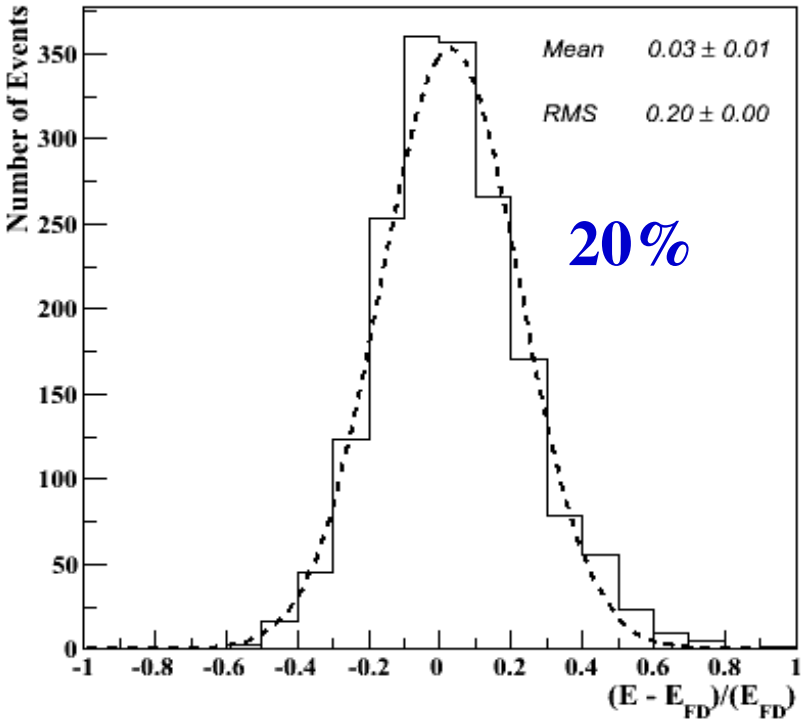
$$E_{FD} = a \cdot S_{38^\circ}^{b}$$

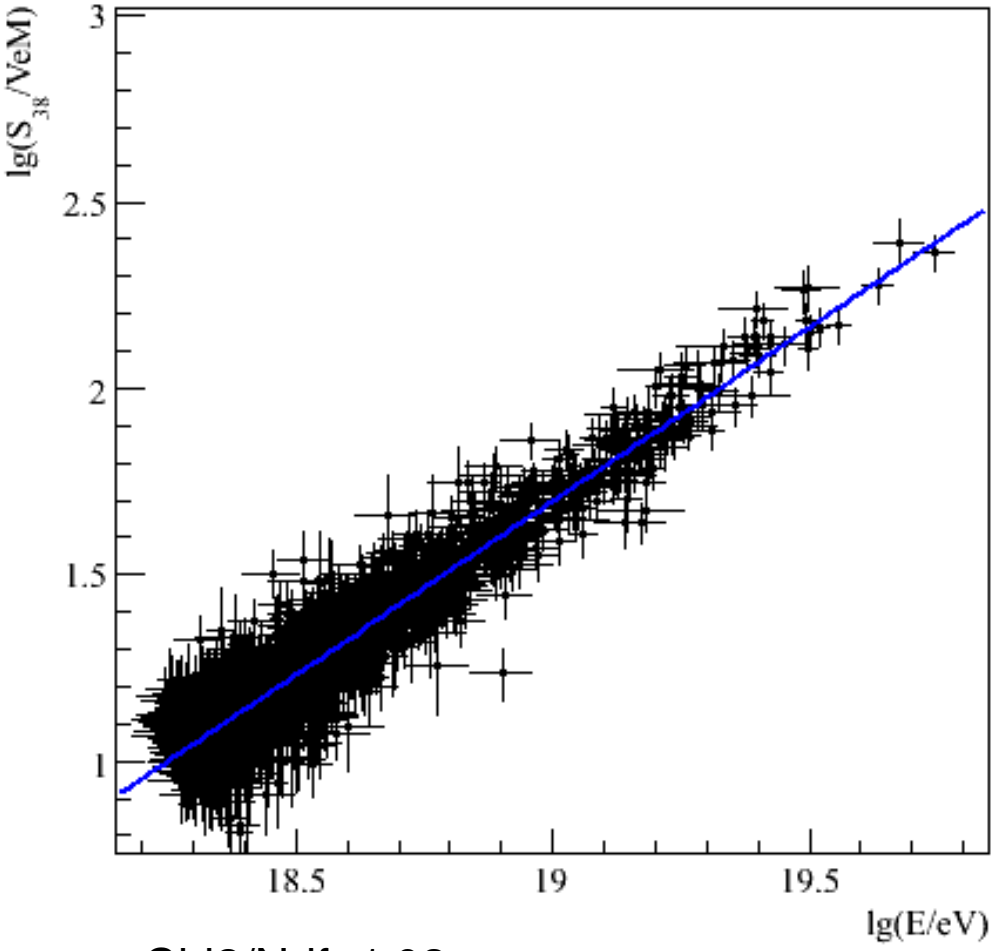
a = 1.50 ± 0.03 x 10^{17} (eV)

b = 1.07 ± 0.01

50 VEM ~ 10^{19} eV

1773 hybrid events



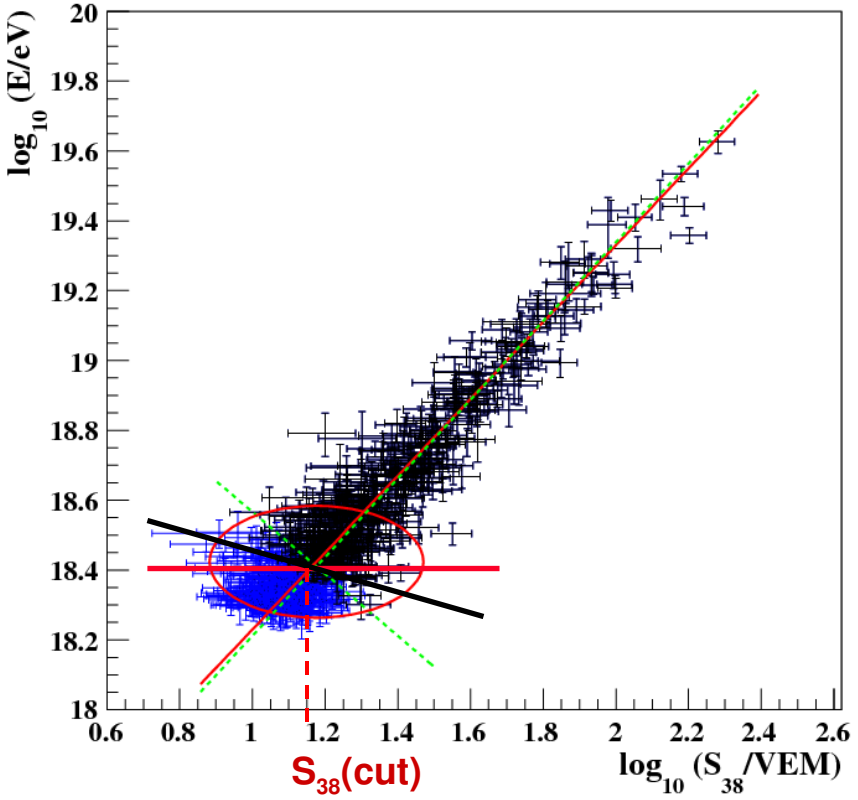


measurement of the energy resolution

16%-S_{38} 9%-E_{FD}

Chi2/Ndf=1.03

The ellipse cut:



To obtain a surface detector energy calibration curve we need consider the trigger efficiency of the surface detector that is lower than 100% for S_{38} (cut) ≃ 15 (VEM), and cuts the events below this limit.

When we reject events below any line cutting the ellipse, we introduce necessarily a bias if we do not consider the resolution on S_{38} and on E_{FD} .

We use a selection criterium for which $(< S_{38} >, < E_{FD} >) = (S(cut)_{38}, E(cut)_{FD})$.

This is obtained by selecting events which are in the 90% C.L. ellipse centered in $(S(cut)_{38}, E(cut)_{FD})$.

Systematics on the calibration curve procedure:

- Ellipse cut systematic

68% C.L. --> a=1.580 +/-0.044 b=1.060 +/-0.008 N=1269

95% C.L. --> a=1.501 +/-0.029 b=1.075 +/-0.006 N=2182

Δa=0.08 Δb=0.015

- Extreme cut(?)

horizontal cut

Vertical cut

Work in progress!!

- Linear-Power law(?)

Systematics FD Energy scale:

30TH INTERNATIONAL COSMIC RAY CONFERENCE

Source	Systematic uncertainty
Fluorescence yield	14%
P,T and humidity effects on yield	7%
Calibration	9.5%
Atmosphere	4%
Reconstruction	10%
Invisible energy	4%
TOTAL	22%

→ 6th Fluor. Meeting

→ Calib. Paper

→ Atm. Paper

→ GAP.

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Systematics: Fluorescence Yield

Status: Model 'Airfly'

-) yield normalization from

M. Nagano et al.,Astropart.Phys.22 (2004), 235 **14%**

-) spectrum and pressure dependence from

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

Improvements:

-) temperature-dependent collisional cross sections and collisional quenching due to water vapor from

B. Keilhauer et al., NIM A 597 (2008) 99 **(5% up to 8%)**

M. Unger at 6th Fluor. Meeting

Systematic: FD Calibration

Source of Error		Porcentual error(%)
FD Analysis	Distribution width	2
PMT QE	Photodiode calibration	1
	Measured photodiode response	2
	PMT response	1
Drum relative response	PMT response	1
Notch filter width effects	Filter transmission vs wavelength	2
	Xe spectrum measurements	1
	Unknown drum distortion of Xe/filter distribution	2
from multiwavelenght paper	Total	4

The accuracy of the absolute drum calibration ~ 6.0%.

(FD Paper line 700 (http://www.phys.lsu.edu/%7Ematthews/publications/prouza_fdbig.pdf))

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Systematic: Atmosphere

Systematic Uncertainties					
Source	$\log(E/\mathrm{eV})$	$\Delta E/E$ (%)	$\sigma(\Delta E/E)$ (%)	$\Delta X_{\max}$ (g cm^{-2})	$\sigma(\Delta X_{\max})$ (g cm^{-2})
Molecular Light Transmission and Production					
Horiz. Uniformity	17.6 – 20.0	1	1	1	2
p, T, u Effects	17.6 – 20.0	0.7	4.8	5.4	11
Aerosol Light Transmission					
Optical Depth	< 18.0	3.6	2.8	3.3	6.1
	18.0 – 19.0	5.1	3.6	4.9	7.4
	19.0 – 20.0	7.9	4.9	7.3	9.4
λ-Dependence	17.6 – 20.0	0.5	2.0	0.5	2.0
Phase Function	17.6 – 20.0	1.0	2.0	2.0	2.5
Horiz. Uniformity	< 18.0	0.3	3.6	0.1	5.7
	18.0 – 19.0	0.4	5.4	0.1	7.0
	19.0 – 20.0	0.2	7.4	0.4	7.6
Scattering Corrections					
Mult. Scattering	< 18.0	0.4	0.6	1.0	0.8
	18.0 – 19.0	0.5	0.7	1.0	0.9
	19.0 – 20.0	1.0	0.8	1.2	1.1

http://www.phys.lsu.edu/%7Ematthews/publications/benzvi_atmos.pdf

Systematics S38:

- Reconstruction Method (Herald)
- Temperature effect on S1000
- ……

Work in progress!!

Conclusions

- Check the results with Ioana (CIC, events selection, calibration parameters).
- Energy calibration seems in agreement with P.R.L. Spectrum paper.
- Work in progress on systematics checking value in FD Paper, ATM Paper etc...