Measurement of the Air Fluorescence Yield with AIRFLY

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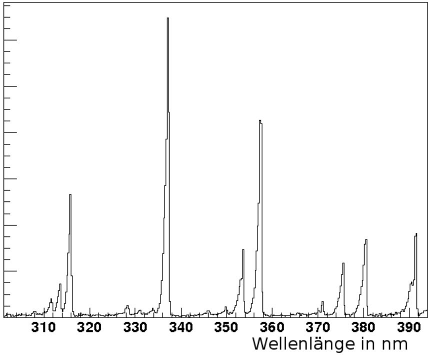
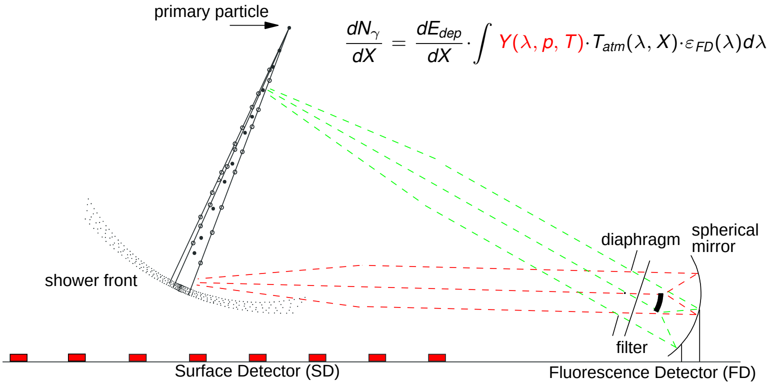


Outline

- Introduction
- The AIRFLY Experiment
- Analysis of the Measurements
  - PMT Measurements - 337nm Line
  - Spectrometer Measurements
- Summary and Outlook

Sketch of a FL-Detektor (e.g. Auger)

Observation of UHECRs



$$\frac{dN_\gamma}{dX} = \frac{dE_{dep}}{dX} \cdot \int Y(\lambda, p, T) \cdot T_{atm}(\lambda, X) \cdot \varepsilon_{FD}(\lambda) d\lambda$$

Our Goal: A better callibration of the measurements of FL-Detectors with $dY < 10\%$

Fluorescence Yield Y

The Fluorescence Yield Y depends on various environmental parameters:

$$Y = Y(p, T, \sigma, E)$$

De-excitation occurs via two different mechanisms:

- radiative transitions (FL-light)
- non-radiative transitions (Quenching)

$$Y = \frac{C \cdot p}{1 + \frac{p}{p'}}$$

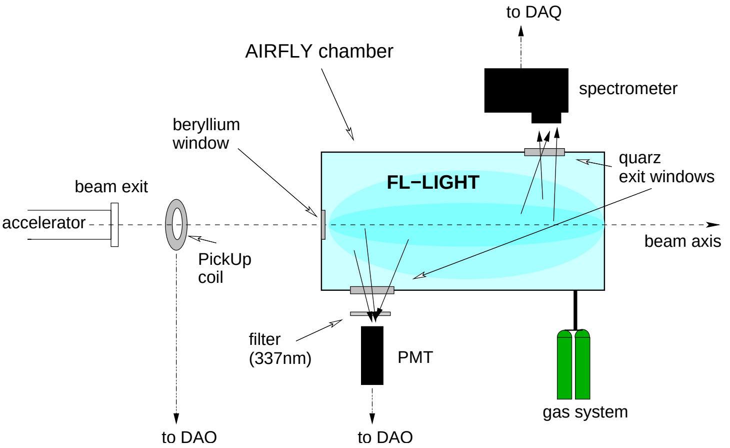
$$p' \propto \frac{\sqrt{T}}{\sigma}$$

$\Longrightarrow$ **AIRFLY - Absolute measurement of these parameters**

The AIRFLY Experiment

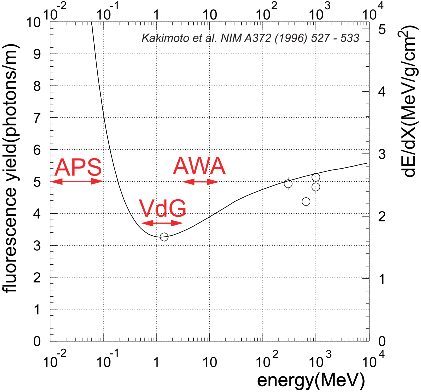
In General

- AIRFLY is a “Thin Target” experiment. ($E_{e^-} = const.$)
- Fluorescence light is observed perpendicular to the beam axis.



AIRFLY - Accelerators

Three accelerators at the Argonne National Laboratory, Chicago (USA), are currently used.



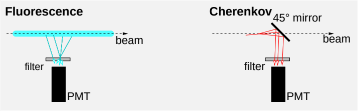
Accelerators at ANL

- Advanced Photon Source (APS): some keV
- Van de Graaff (VdG): 1-3 MeV
- Advanced Wakefield Accelerator (AWA): 3-15 MeV

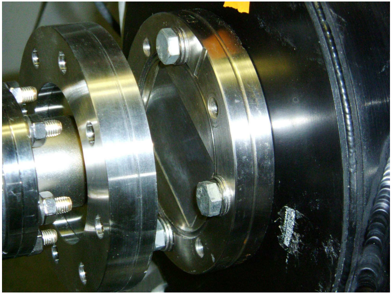
AIRFLY - Chamber

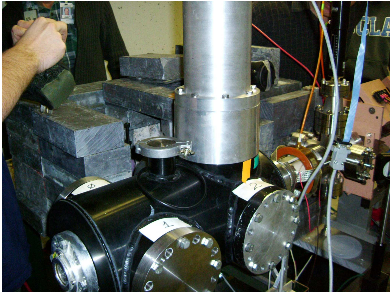
Properties

- Pressure precicely controlable
- Gas composition variable
- Moving Mirror for Cherenkov Measurement

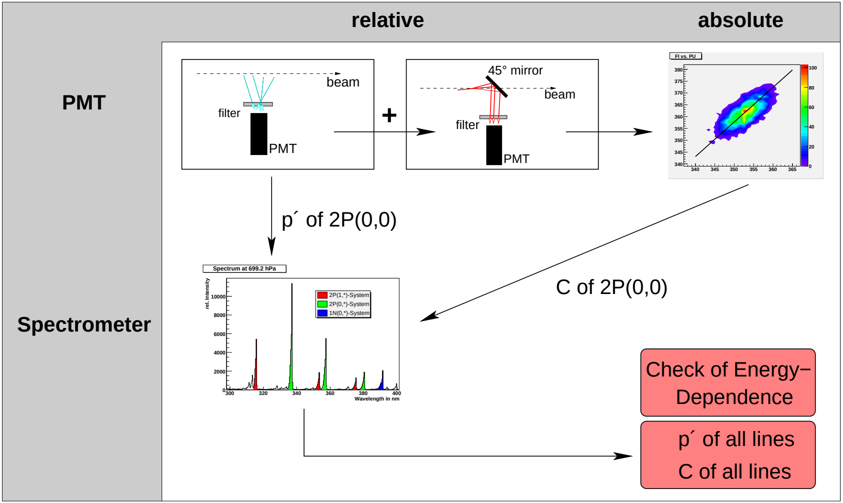


- Planned: New chamber with cooling device



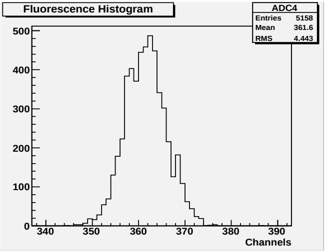


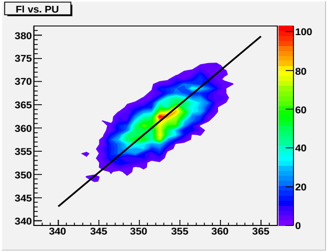
Philosophy of Measurement

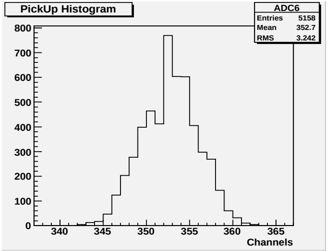


PMT Measurements of 2P(0,0) (337nm line)

Structure of the Raw Data







- PMT and PickUp signals correlated
- Slope is estimator for fluorescence signal (Y_{rel})
- One slope for each pressure!

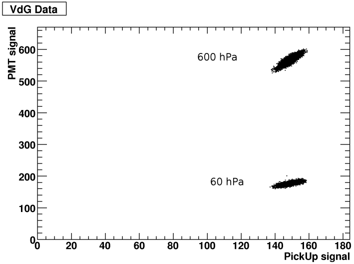
Differences of AWA and VdG data

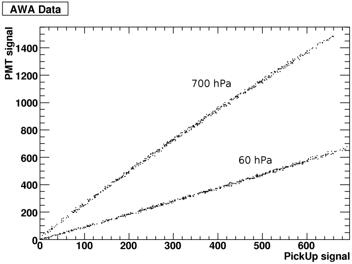
Van de Graaff:

- Small fluctuations, narrow range on PickUp-axis
- See data as one point at the coordinates of the means.

Advanced Wakefield:

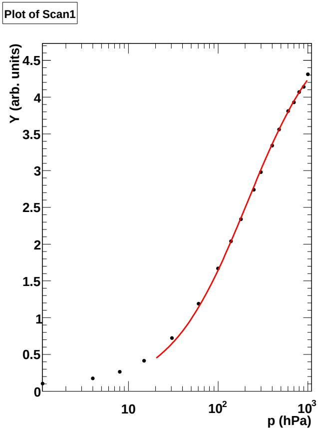
- big fluctuations, wide range on PickUp-axis
- Use slope of fitted line.

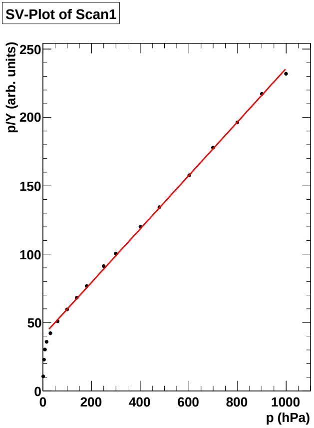




Plots of the relative Yields

- The slope is plotted over the pressure of each run as an estimator of the FL-signal
- The red lines are fits to the data.





Deviations from expected behavoir at low pressures
⇒ escaping secondary electrons!

Correction at low Pressures

Introduced by Paolo Privitera

At low pressure secondary electrons escape the FOV

- less Yield observed than expected
- increases results for p' up to 10% for N_2
- it's a geometrical problem $\rightarrow$ simulations

Changed parametrisation for observed Yield:

$$Y = \frac{C \cdot p}{1 + \frac{p}{p'}} \cdot F(p)$$

Taking a Ratio R

Compare N_2 and Air, so $F(p)$ cancels:

$$R = \frac{Y_{N_2}}{Y_{Air}} = \widehat{C} \cdot \frac{1 + \frac{p}{p'_{Air}}}{1 + \frac{p}{p'_{N_2}}}$$

Simulations (for crosscheck)

Simulations suggest:

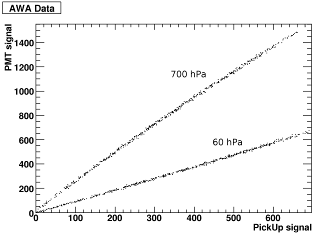
$$F(p) = \left(\frac{p}{1000hPa}\right)^{0.027}$$

$$F(20hPa) \approx 0.9$$

Preliminary Results for PMT data

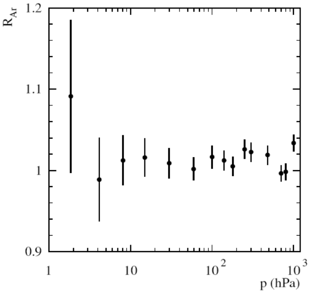
Method

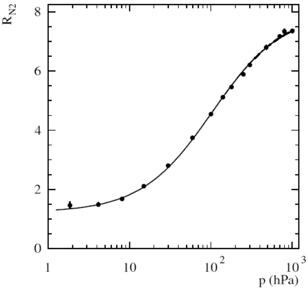
- AWA data was used, because:
  - VdG beam not optimized (spotsize, position)
  - low energy $\rightarrow$ large spread at entrance, multiple scattering
  - VdG results consistent, but large systematic errors
  - AWA data large range on PickUp, beam optimized $\rightarrow$ higher quality, lower statistics!
- Linear fit of scatter plots ($S_{PMT} = S_{PickUp} \cdot Y + b$)
- Y as estimator of the FL-Yield
- Plot of $R_{N_2} = \frac{Y_{N_2}}{Y_{Air}}$ and fit
- **Or:** Plot of $R_{Air} = \frac{Y_{Air}}{Y_{Air+Ar}}$



Preliminary Results for PMT data

The plots R_{N_2} and R_{Air}





- All points consistent with unity
- No effect of argon within our accuracy
- Argon can be neglected

- function describes data points very good!
- Low statistical uncertainty
- Numbers: **next slide**

Preliminary Results for PMT data

Results

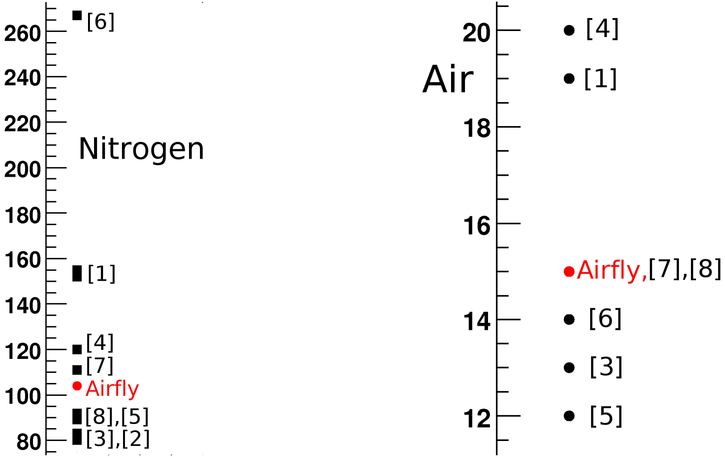
p' (hPa)	Ratio	Simulation	no correction
Air	15.9 ± 0.7	15.3 ± 0.8	20
N_2	104 ± 5	101 ± 4	116

Error estimation:

Source	$\Delta p'_{N_2}$ (hPa)	$\Delta p'_{Air}$ (hPa)
slope fit range	3.6	0.50
background	2.1	0.40
pressure fit range	0.3	0.03
absolute pressure	0.1	0.10
statistical	2.7	0.33
TOTAL	5.0	0.73

Preliminary Results for PMT data

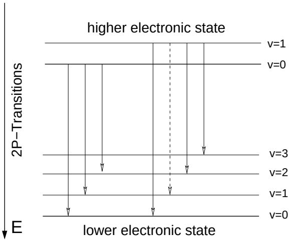
Comparison of p' to other experiments

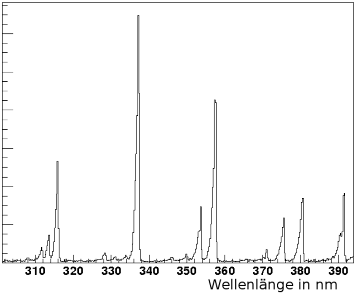


[1] Nagano et al. (2003,2004), [2] Ulrich et al. (2005), [3] Mitchell et al. (1970), [4] Bunner (1967), [5] Brocklehurst et al. (∼1970), [6] Davidson and O'Neil (∼1970), [7] Hirsh et al. (∼1970), [8] Waldenmaier (2006)

Spectrometer Measurements

The spectrum itself



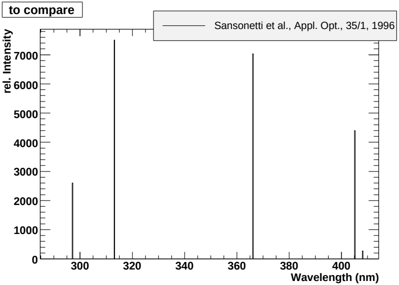


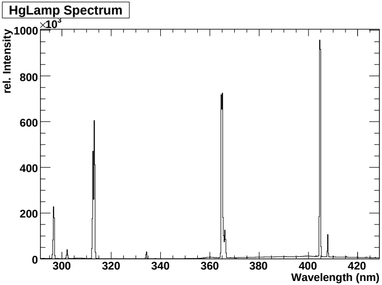
Properties

- Seven major lines
- Three Systems: 2P(0,*), 2P(1,*), 1N(0,0)
- Constant intensity ratios within a system (Franck-Condon principle) $\rightarrow$ ONE p' per system!
- O_2 has no lines in this range, acts only as quencher!

Calibration
Spectrometer Calibration with Hg-pencil lamp

Compare well known spectrum to measured spectrum:

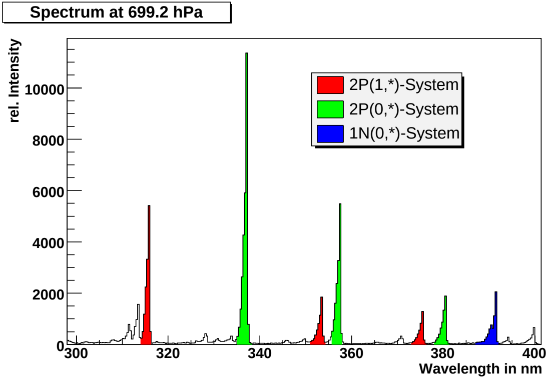


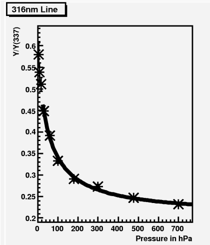


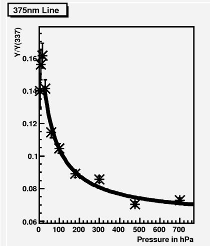
A relative normalization was parametrised and used to correct the spectra. Another aproach using an absolute halogen lamp is studied, which will improve this calibration

Analysis of the Spectra

- Subtraction of background
- Correct with parametrisation of callibration
- Integrate peaks and compare to 2P(0,0)

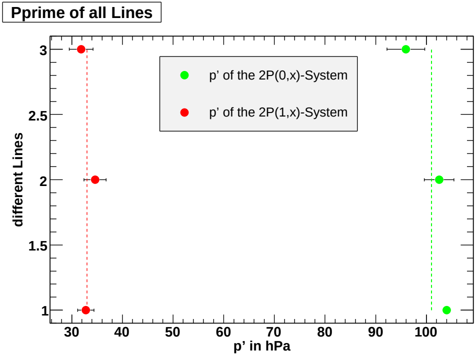






Some preliminary Results for spectrometer data

p′ **values** of the seven lines for a scan with N_2. They are almost equal for each system!



Intensity ratios:

- Consistent with Theory (Gillmore et al.) within 10% (due to calibration)
- Stable over whole pressure range.

Summary and Outlook

Summary

- AIRFLY is up and running
- relative data has been taken with PMT and spectrometer
- Correction at low pressures
- Results are preliminary but promising

Outlook

- AIRFLY will get a new chamber
- Cherenkov measurement have to be included
- Temperature dependence will be measured
- Effect of humidity will be investigated
- Energy dependence will be checked

Thanks!