AIRFLY: Measurement of the Air Fluorescence induced by electrons

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For the Airfly collaboration

9th Topical Seminar on Innovative Particle and Radiation Detectors
23-26 May 2004 Siena, Italy

The AIRFLY Collaboration

AIRFLY: Air Fluorescence Induced by Electrons in a Wide Energy Range

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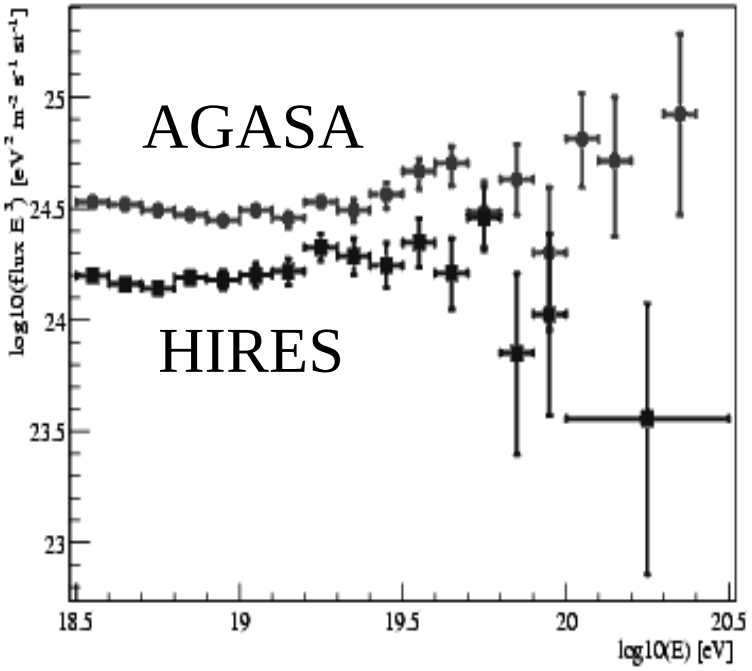
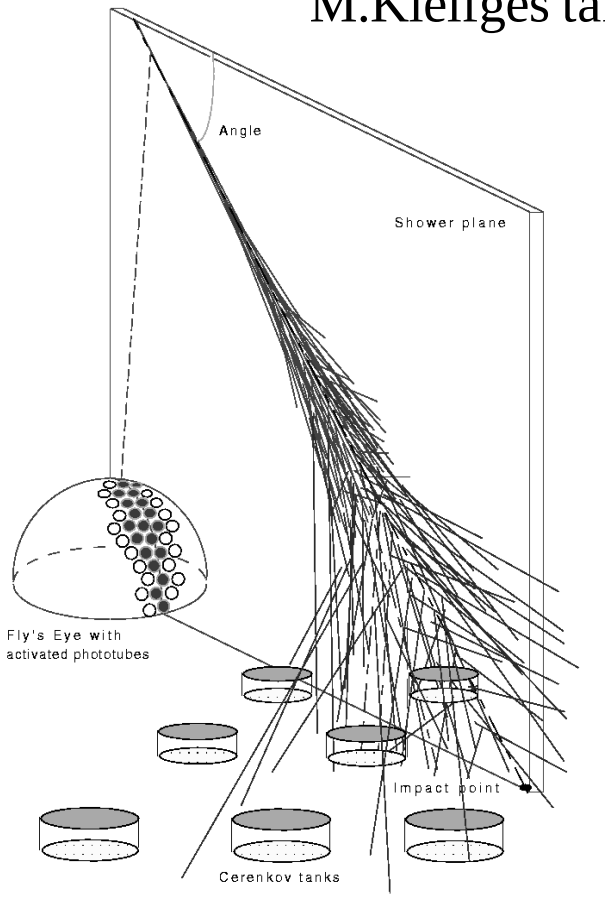
Air Fluorescence Cosmic Rays Experiments

300-400 nm light from de-excitation of atmospheric nitrogen
(fluorescence yield ~ 4 photons /m /e^-)

- Reconstruction of the full longitudinal profile
- Calorimetric measurement of the shower energy



M.Kleifges talk



We need to measure the fluorescence yield to better than 5% (even 10% difficult....)
Actual error 15-20%

Fluorescence Yield in Air

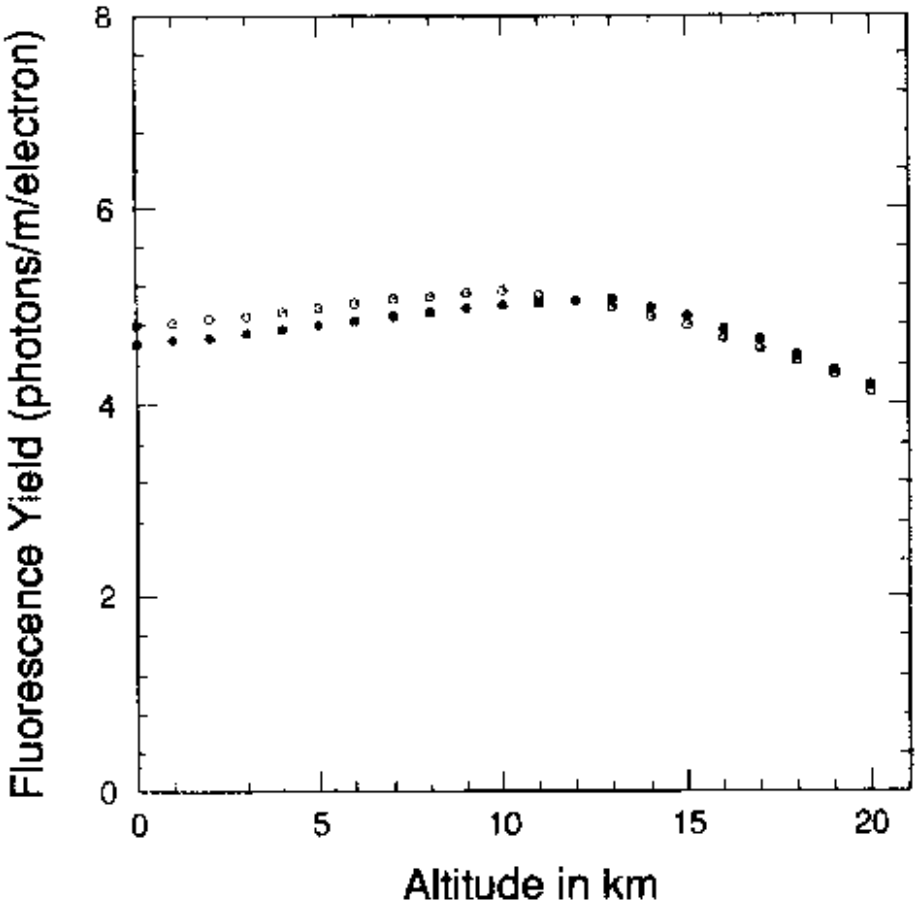
$$Y_?(???) \frac{dE}{dX}(X) ? \frac{A_?}{1 + B_? ??T^{1/2}}$$

Collisional de-excitation (mainly O_2)

Electron energy loss

Atmospheric density

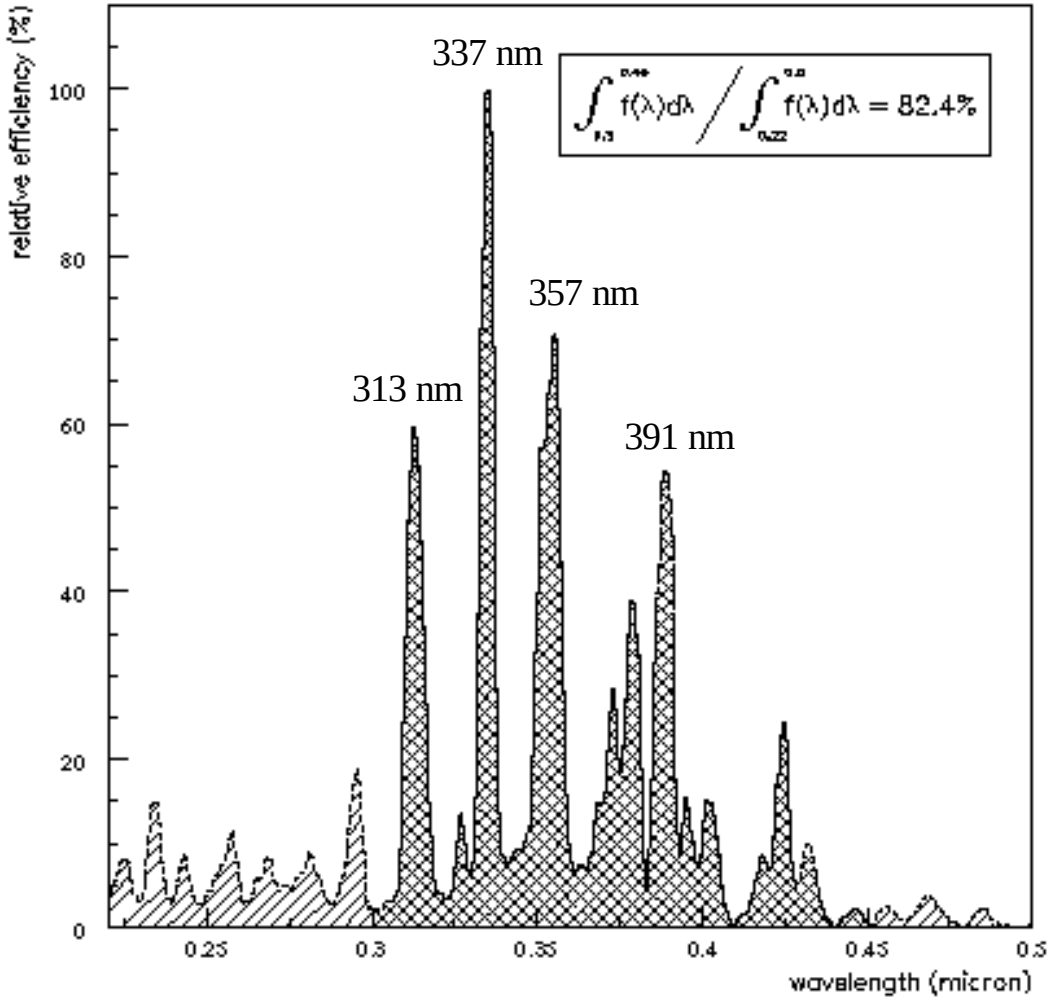
$$\frac{\text{Yield-}N_2}{\text{Yield-Air}} \sim 6$$



? ? **dependence:** Bunner Ph.D Thesis (Cornell Univ. **1967**)
measurements with a and 50 keV electrons totally absorbed in air

Atmospheric trasmission
Raileigh scattering ~1/? 4

~ 300 - 400 nm

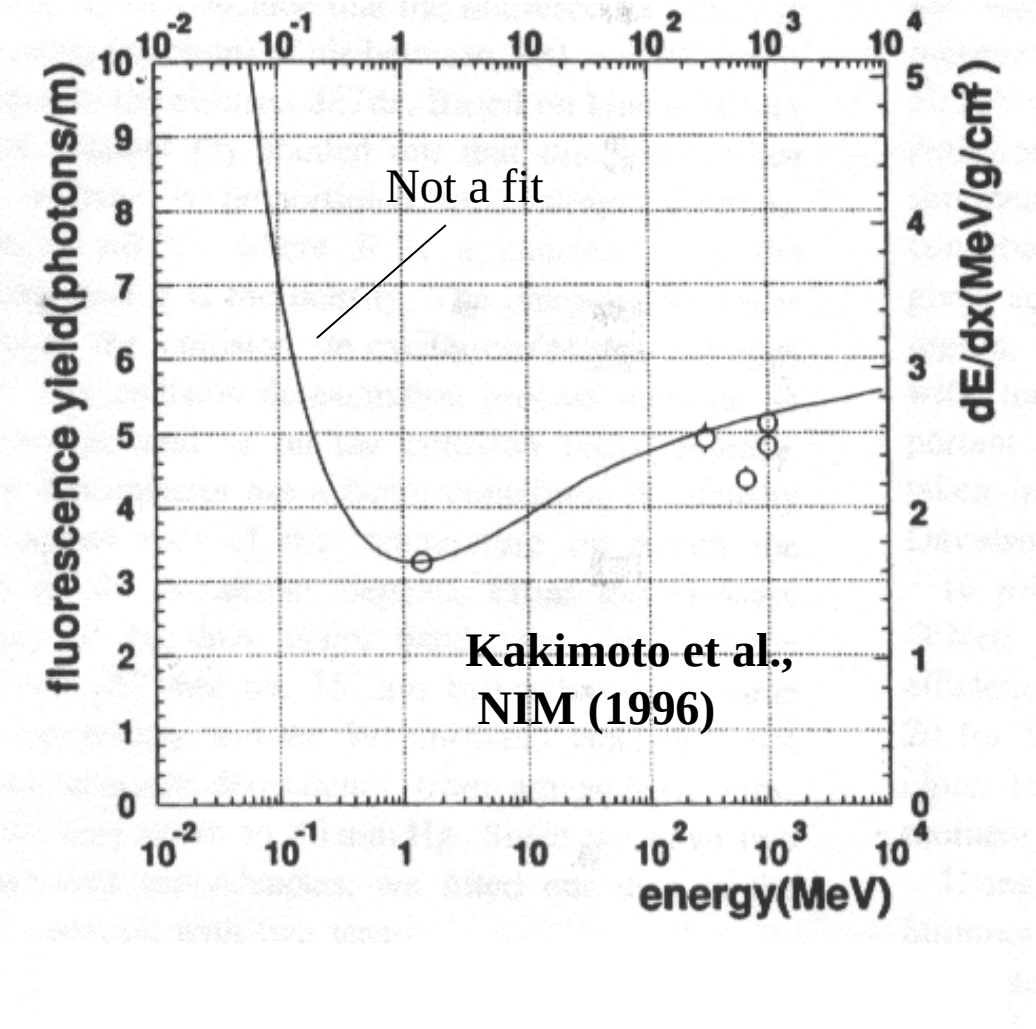


? **electron energy dependence**

? 2 experimental points:
- 1.4 MeV ^{90}Sr
- around 1GeV e-beam

Nagano et al., astro-ph/0303193
ß source (0.85 MeV)

? ? ? ? ?
no measurements exist in the range of critical energy of electrons in air (80 MeV)
Most of energy deposited by 1-few hundreds MeV electrons/positrons



Yield vs altitude

? **pressure dependence:**

Nagano et al., astro-ph/0303193

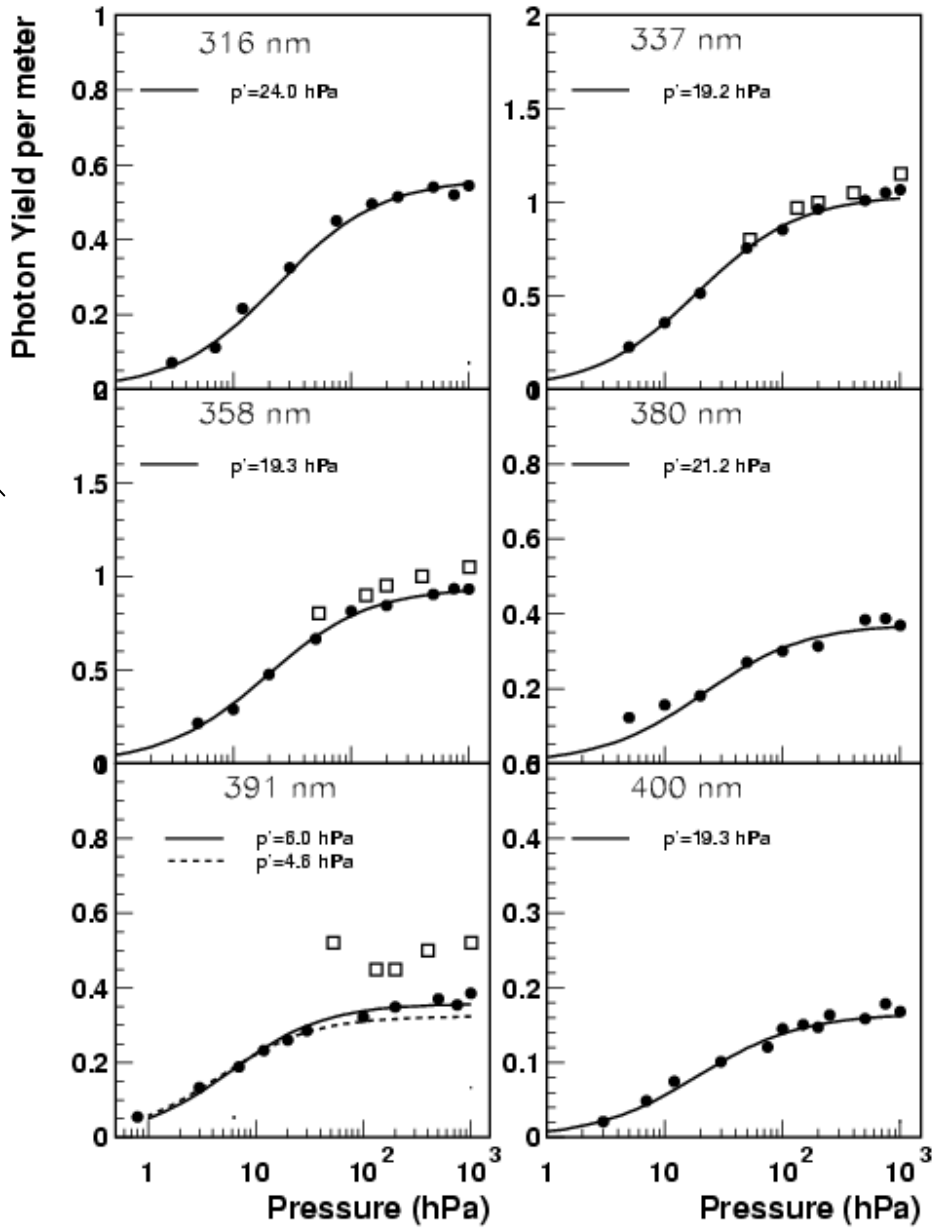
$$Fl.\ Yield \propto \frac{p}{1 + p/p'}.$$

? **temperature dependence**

$$p' \propto 1/(\sigma_{coll}\bar{v}),$$

~ T independent $(\propto \sqrt{kT})$

T dependence has never been measured



AIRFLY Physics Program

- **Electron-positron beam at the Beam Test Facility of the L.N.F.**
- **Absolute measurement of fluorescence yield:**
  - **new method which avoids the problem of the absolute PMT calibration**
- **Relative measurements of fluorescence yield:**
  - **Energy dependence**
  - **Spectrum from spectrophotometer**
  - **P and T dependence**
  - **gas dependence**
    - **N_2 O_2 Ar mixing**
    - **artificial dry air**
    - **humidity**

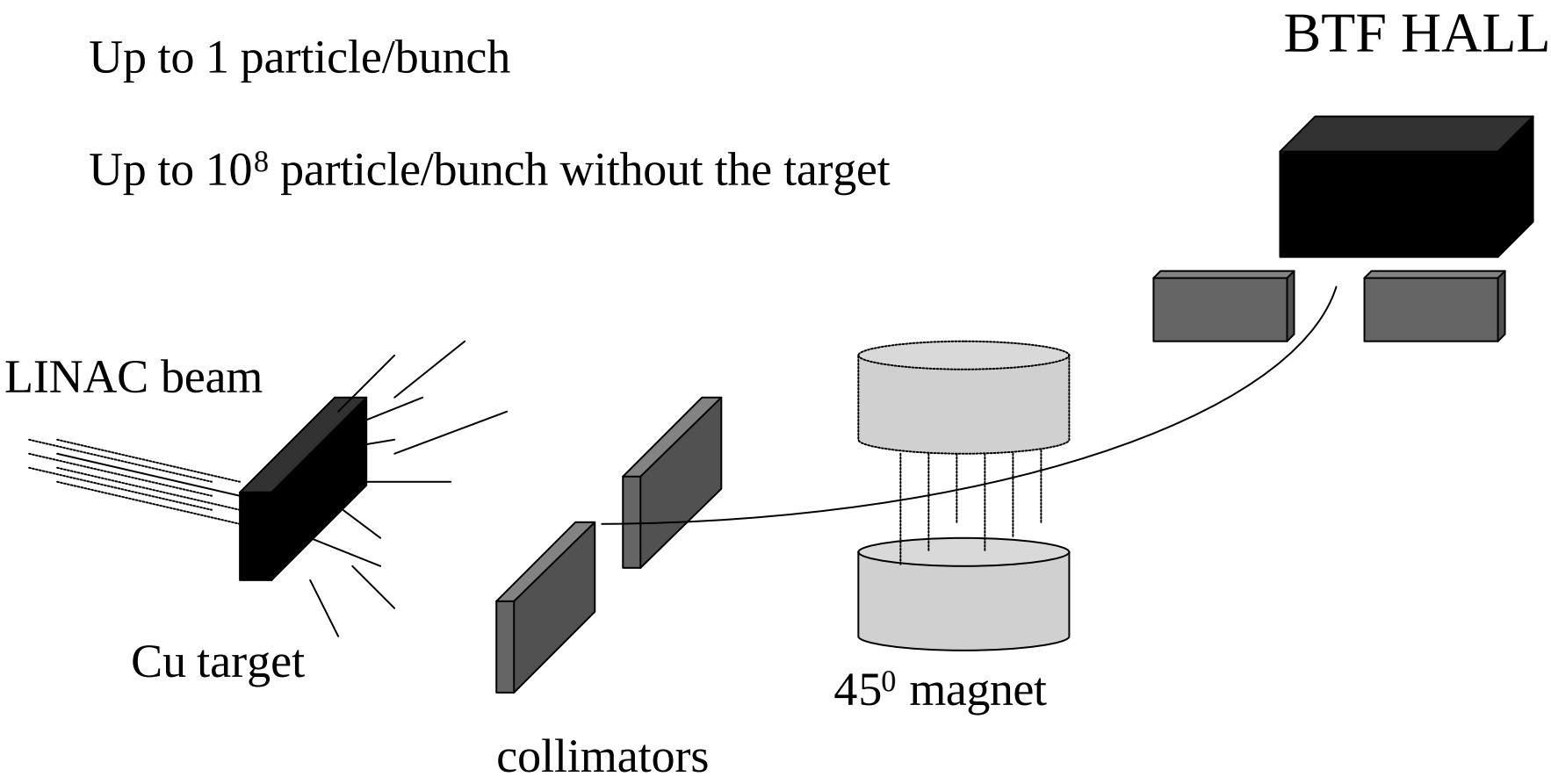
The Beam Test Facility

50-750 MeV

Bunch: 1-10 ns, up to 50 Hz

Up to 1 particle/bunch

Up to 10^8 particle/bunch without the target



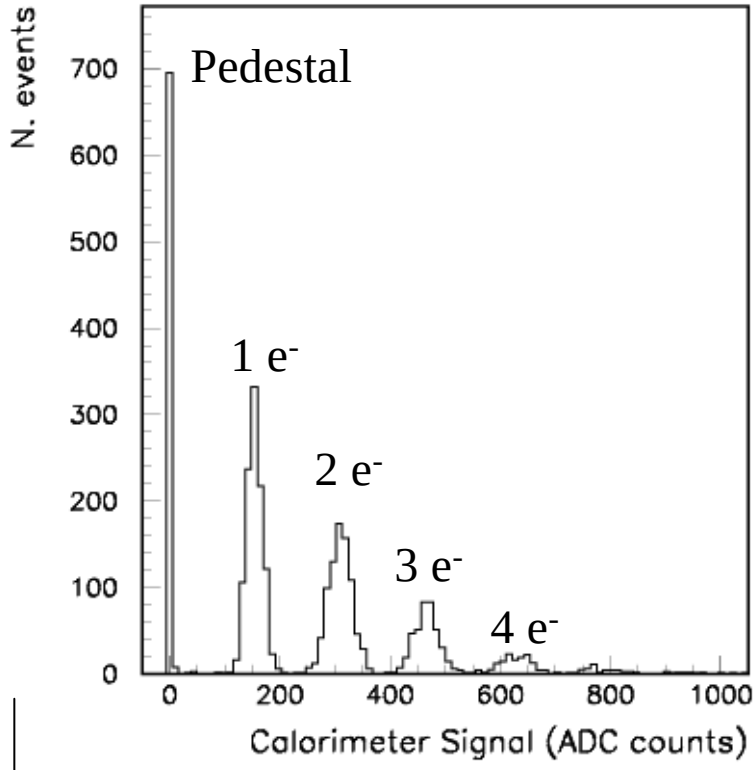
… more details in the P.Valente talk

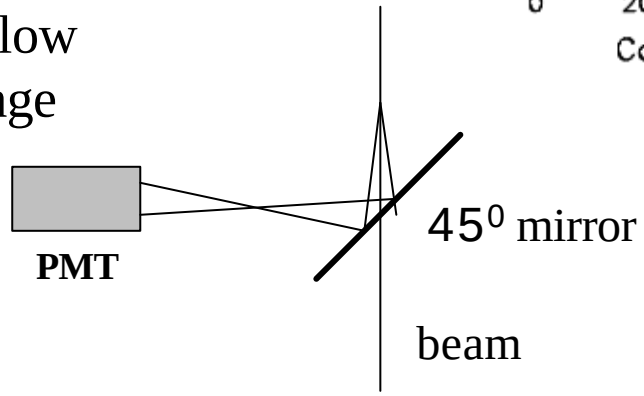
Beam Monitoring

? A calorimeter is used to monitor the beam intensity up to 1000 e^-/bunch

It's sensitive to the single electron
? absolute calibration of N_e

? For N_e > 1000 e^-/bunch the beam is monitored using a Cherenkov counter. Neutral density filters allow a very large dynamic range



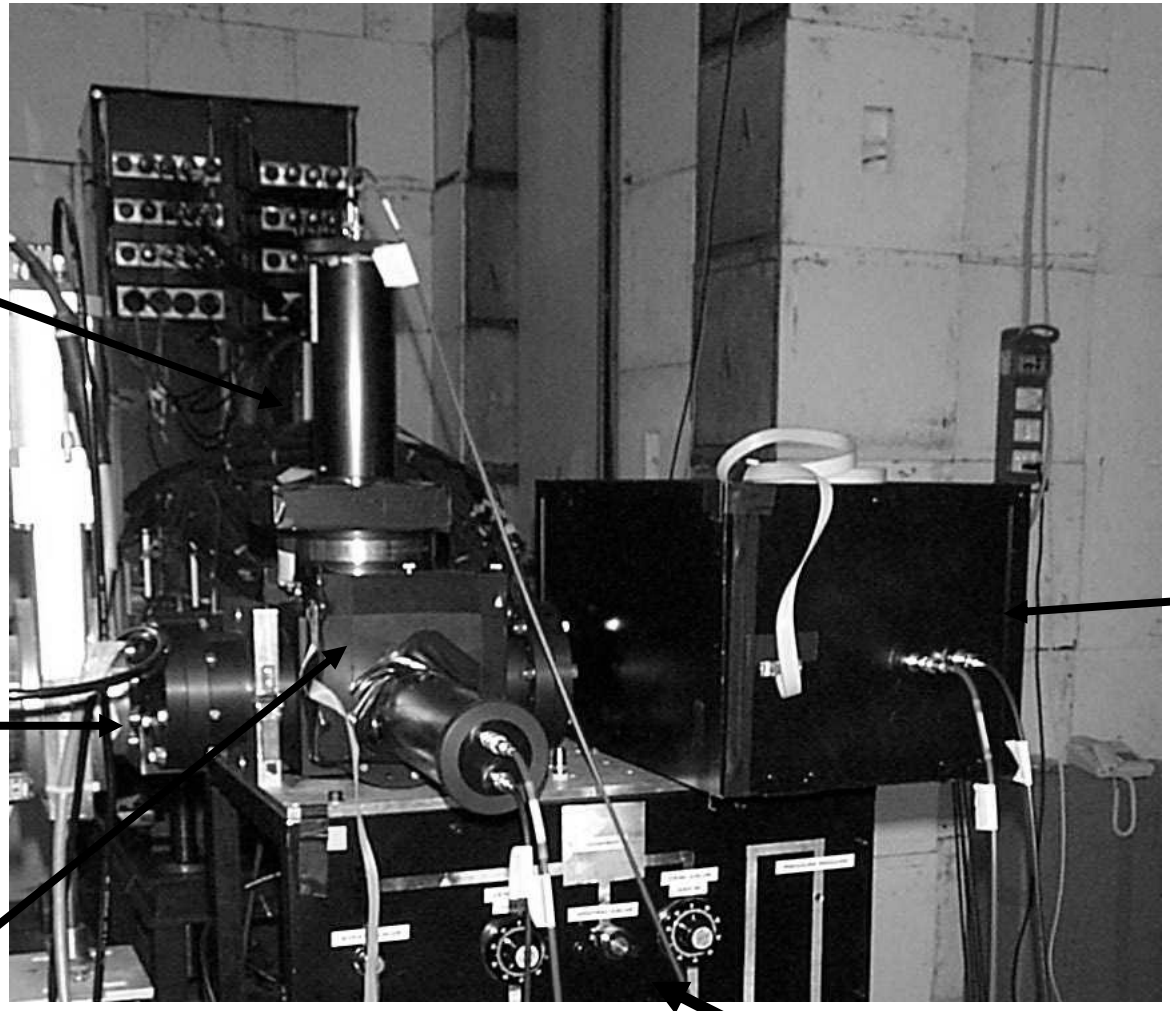


? Scintillators fibers are used to monitor the beam spot position and size

… more details in the P.Valente talk

AIRFLY Fluorescence Chamber Prototype

Six way cross chamber



PMT

(lead for shielding)

beam

Cherenkov beam monitor

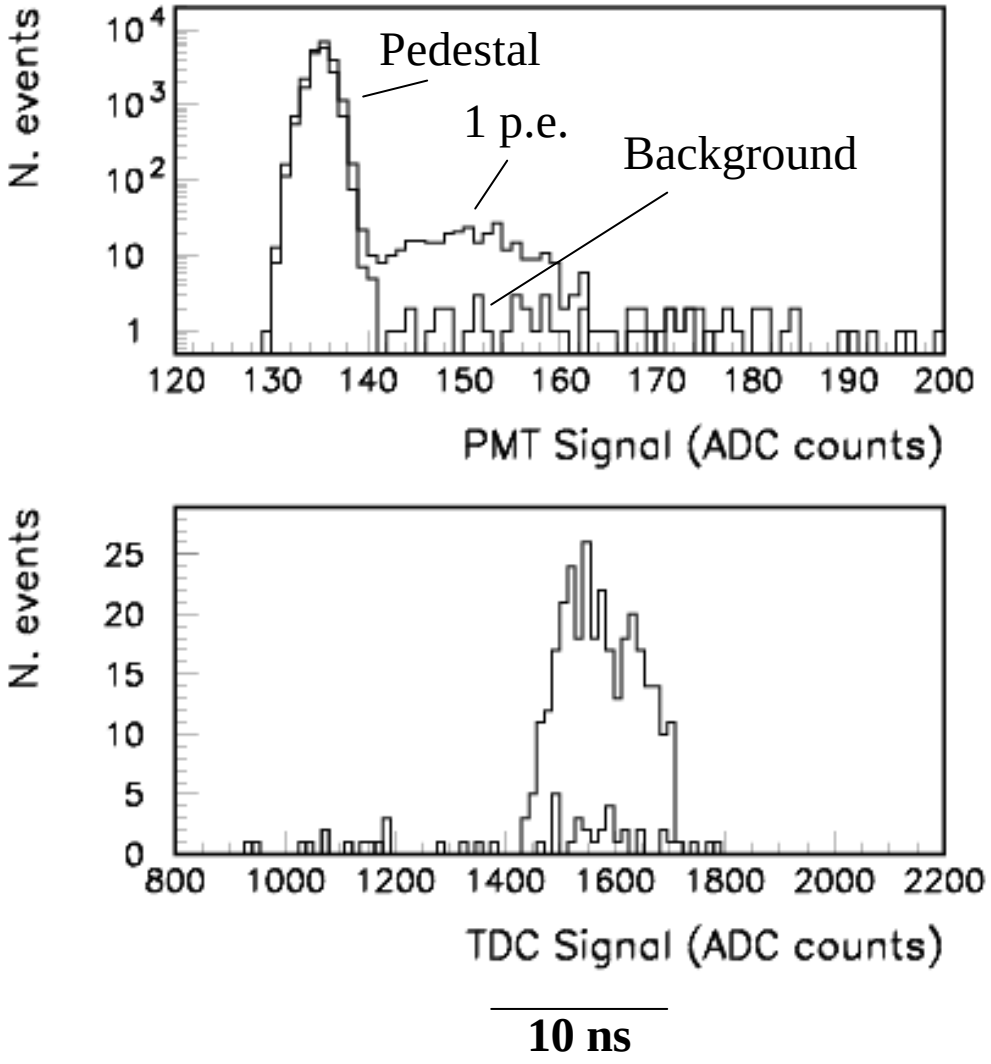
Filter wheel: UG6, 337nm … interf. filters
black filter for background

Gas system: N_2 and dry air
remote control of gas, pressure, temperature and humidity

Chamber Shielding

Single Photoelectron Run (< 1000 e^-/bunch)

The beam intensity can be tuned in order to have on average 1 photoelectron.



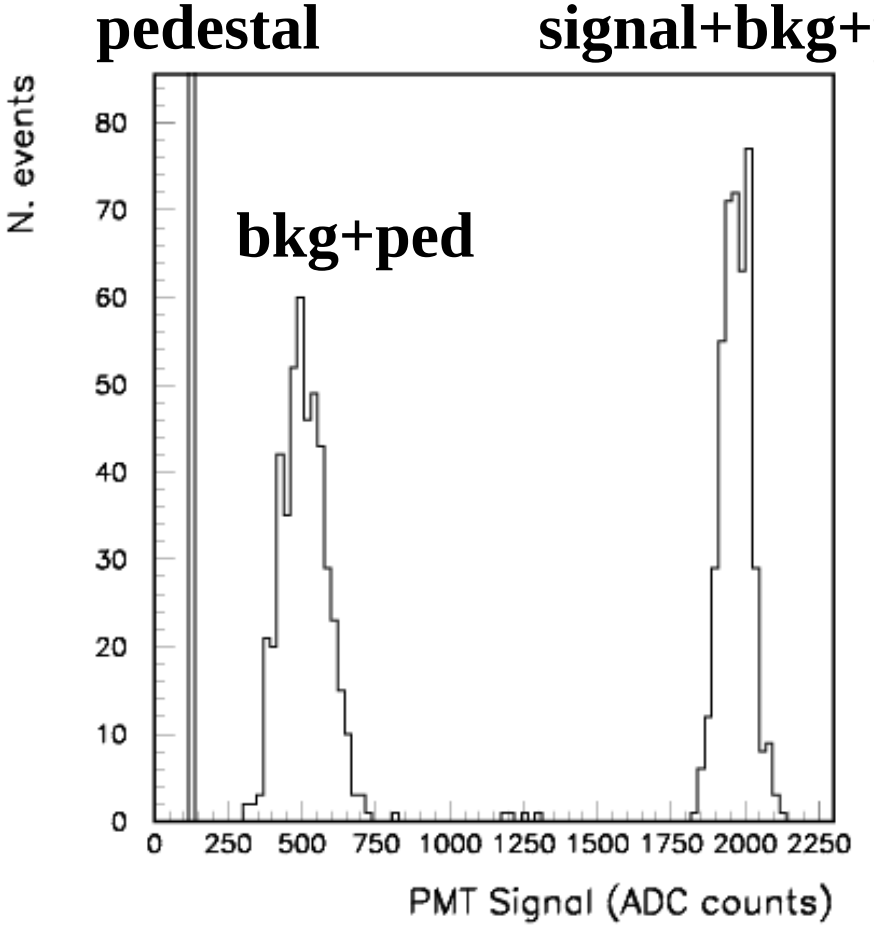
337 filter – Air
N_e ~ 500 e^-/bunch

Signal was around 1% of all triggers.

Back/Sign ~ few %

Run with High Intensity Beam (10^8 e^-/bunch)

High intensity beam will be used for spectrum measurements



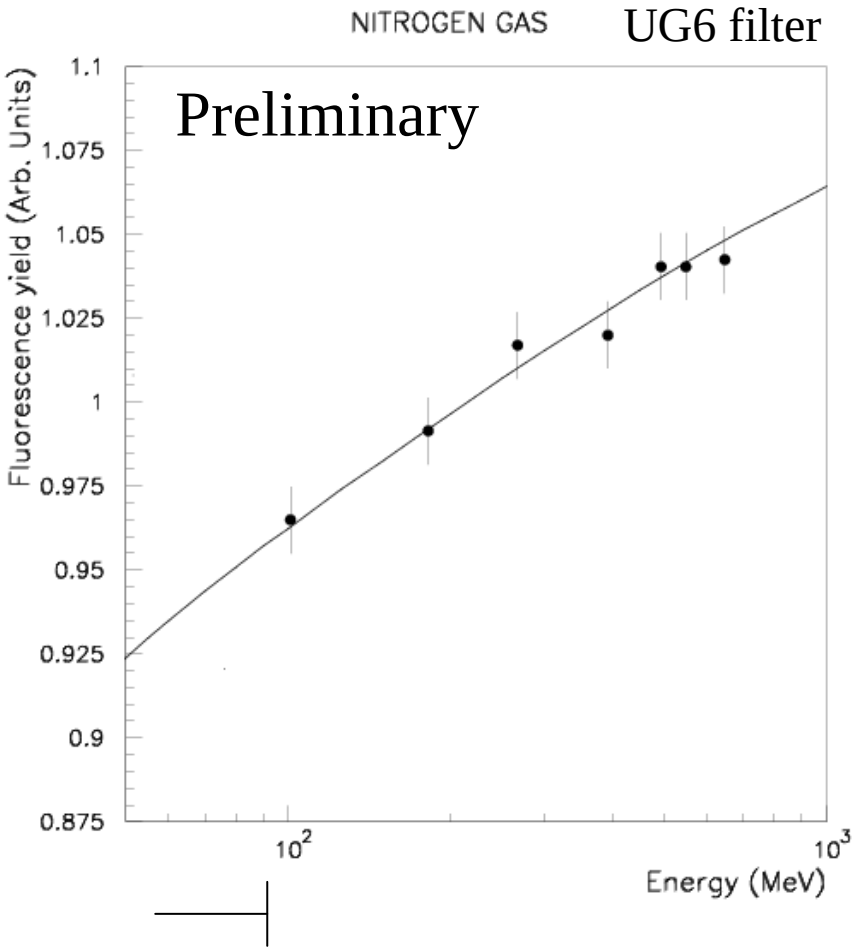
25% bkg. with 337 nm filter in air

improvements by better shielding+acceptance

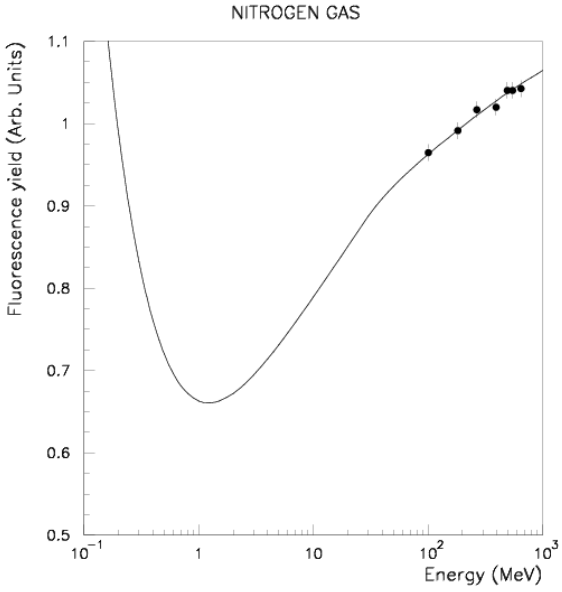
Lower bkg. expected with CCD (small area detector) that will be used for spectrum measurements

Energy Dependence of Fluorescence Yield

$$\frac{N_{p.e.}(\text{fluor.})}{ADC_{cal} \times E/442}$$



The scan was performed several times also in air with consistent results.



Limited by multiple scattering on 1.5 mm thick exit Al window. The scan went down to 50 MeV.

Positrons (493 MeV) gave same yield within 3%

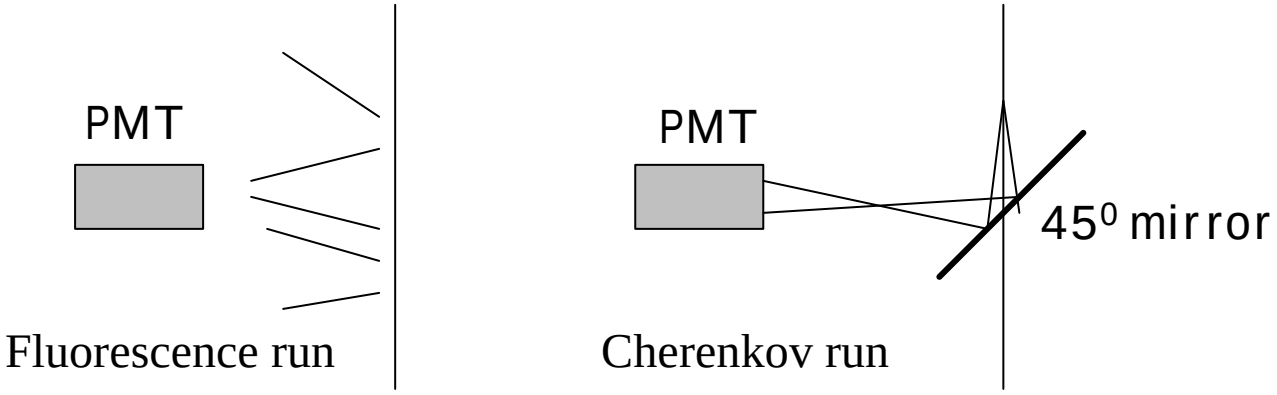
New Method for Absolute Measurement of Fluorescence Yield

✍IDEA: normalize to well known process (cherenkov emission) to cancel detector systematics. The normalization is done at ? ?= 337 nm.

$$N_{337}(\text{fluor.}) = FLY \times Geom_{fluor} \times T_{filter} \times QE_{337} \times N_{electr.}$$

measured — known — MC — Cancel! — relative meas.

$$N_{337}(\text{cher.}) = CHY \times Geom_{cher} \times T_{filter} \times QE_{337} \times N_{electr.}$$

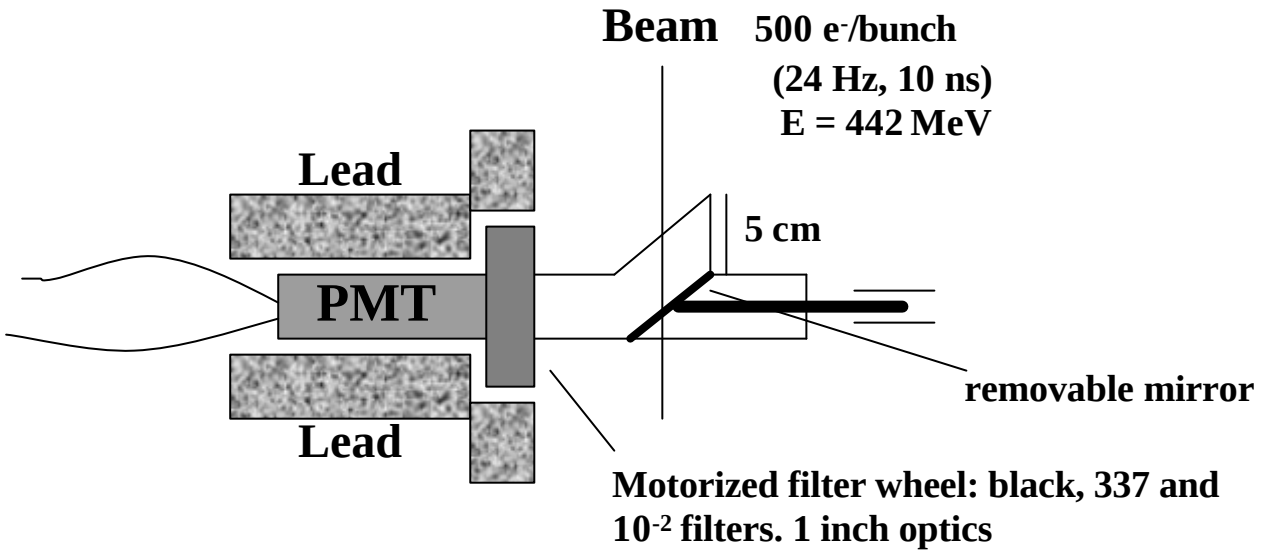


? Systematic error potentially = 5%

? First tests very encouraging!

Very Preliminary Absolute Measurement

Very simple experimental setup:



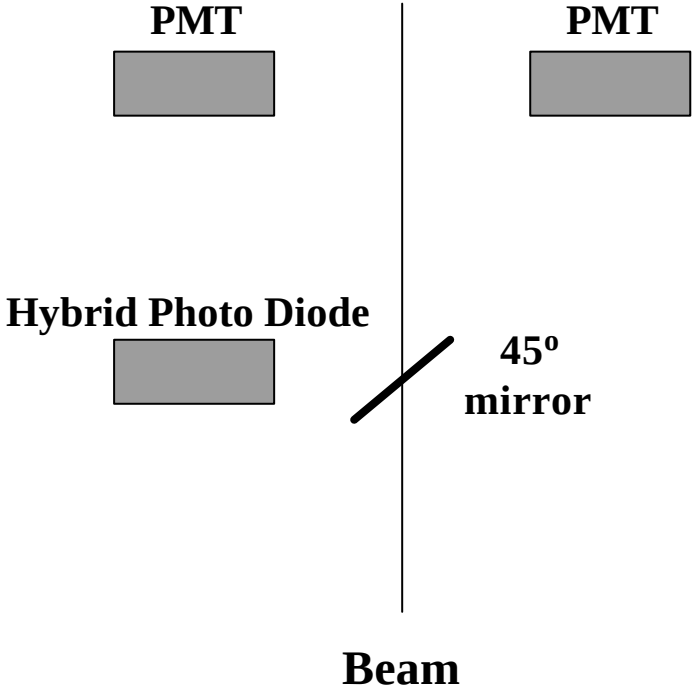
$$Y_?^{fluor}(337\ nm) \sim 1.2 \times 10^{-2}\ ??/\ cm$$

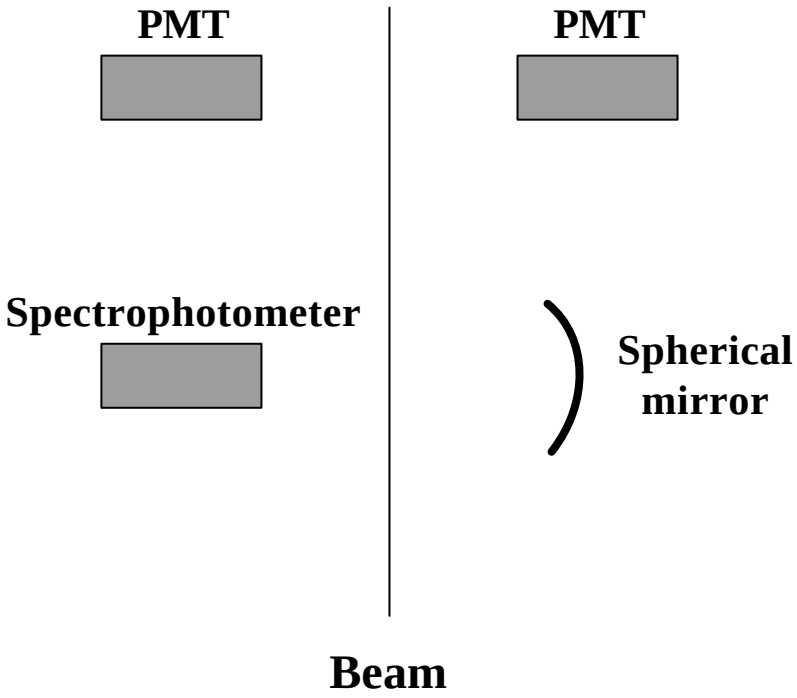
Nagano et al. (astro-ph/0303193) gives 1.4×10^{-2} ??/cm

Final Experimental Setup

Low intensity run:
Absolute measurement
Energy scan

High intensity run:
Spectrum
P, T scan
Gas dependence



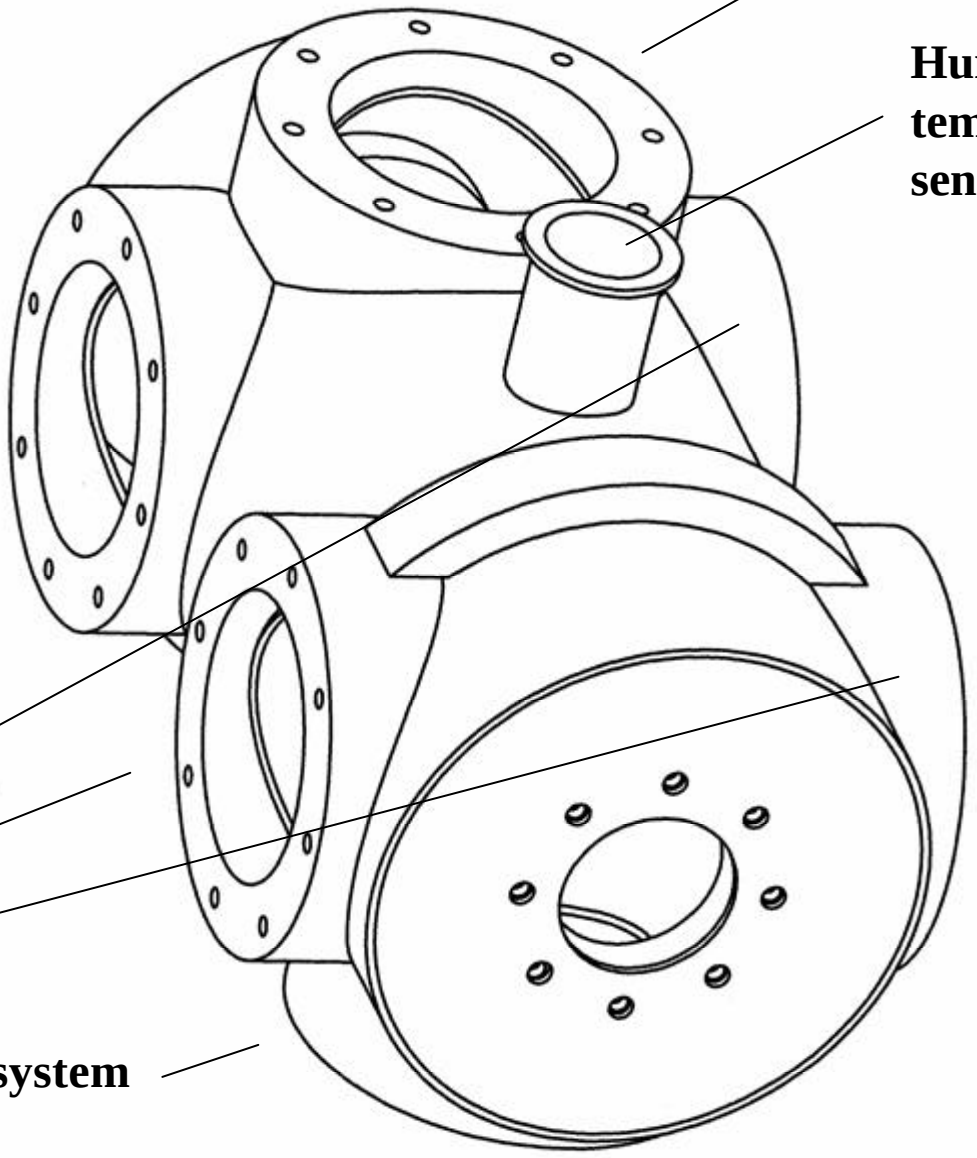


AIRFLY Chamber

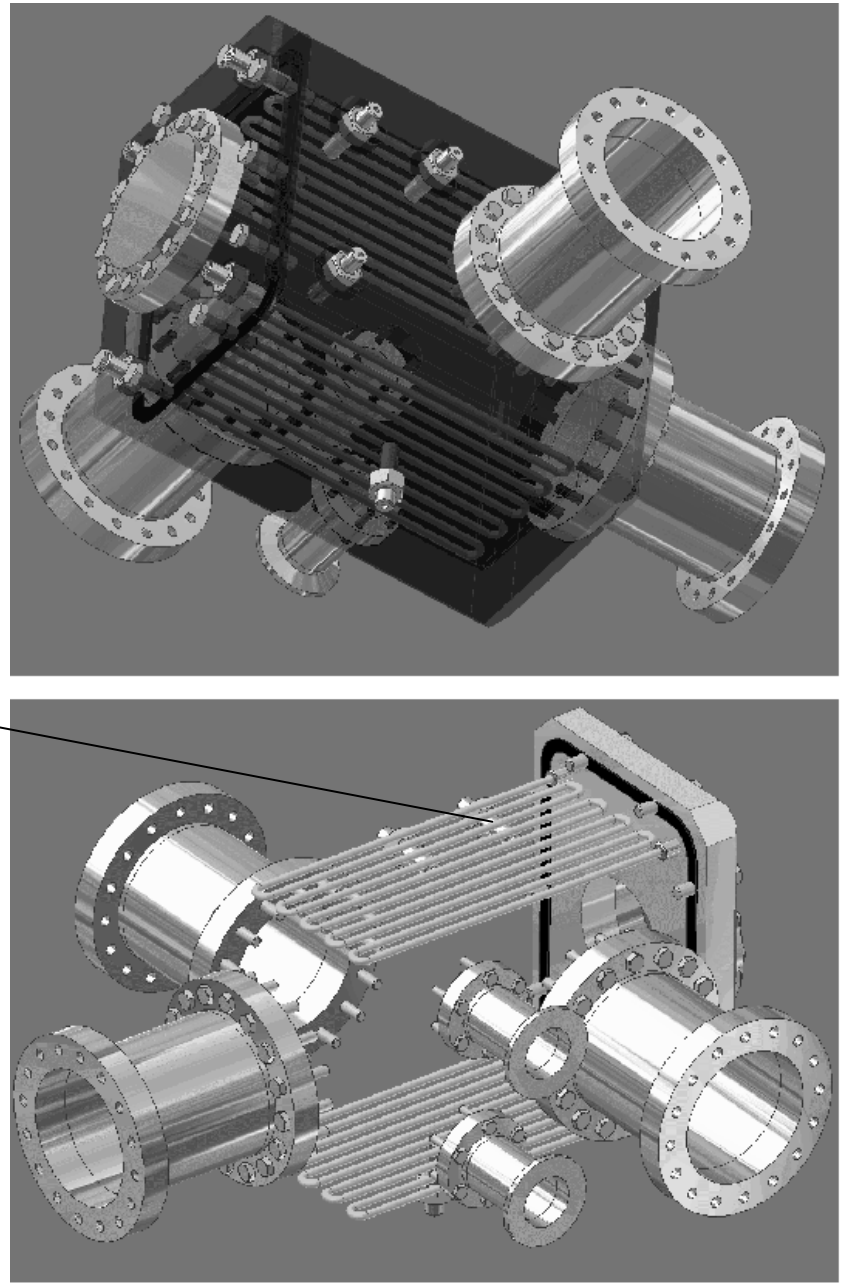
Chamber: Al 3 mm thick

CF100 entrances to accommodate experimental instruments

0.5 mm thick Be window
(E = 50 MeV)



Temperature Measurements

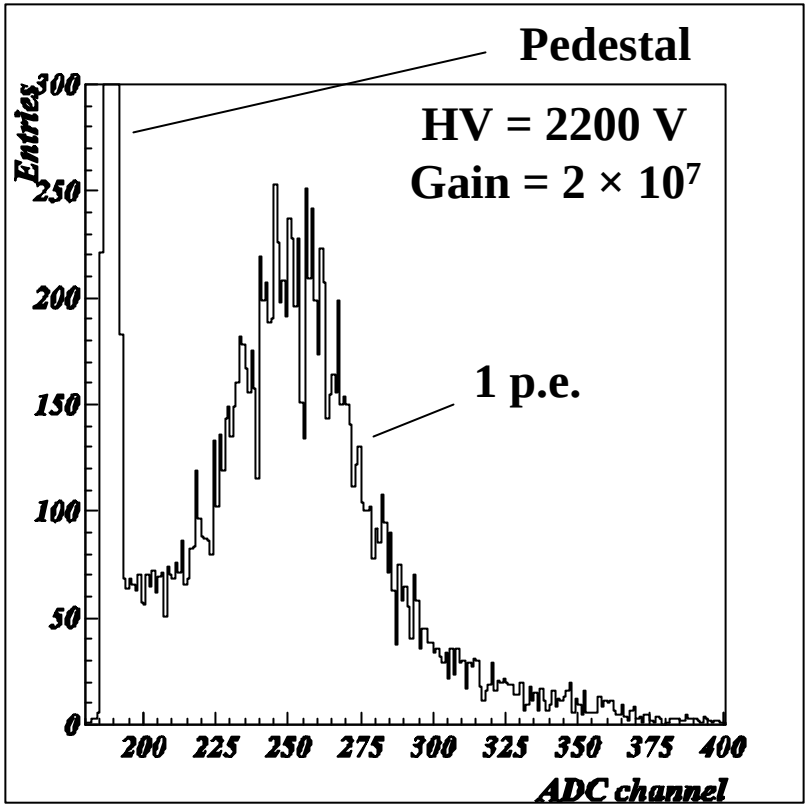


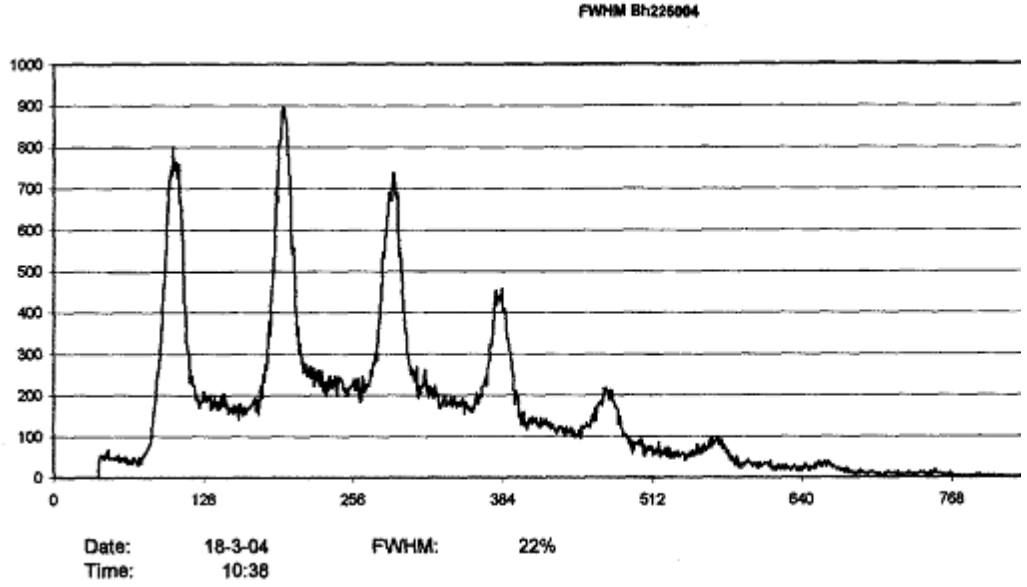
Detectors

4 Hamamatsu H7195PX PMT's
absolutely calibrated

2 inches interferential filters
(up to know 1 inch)

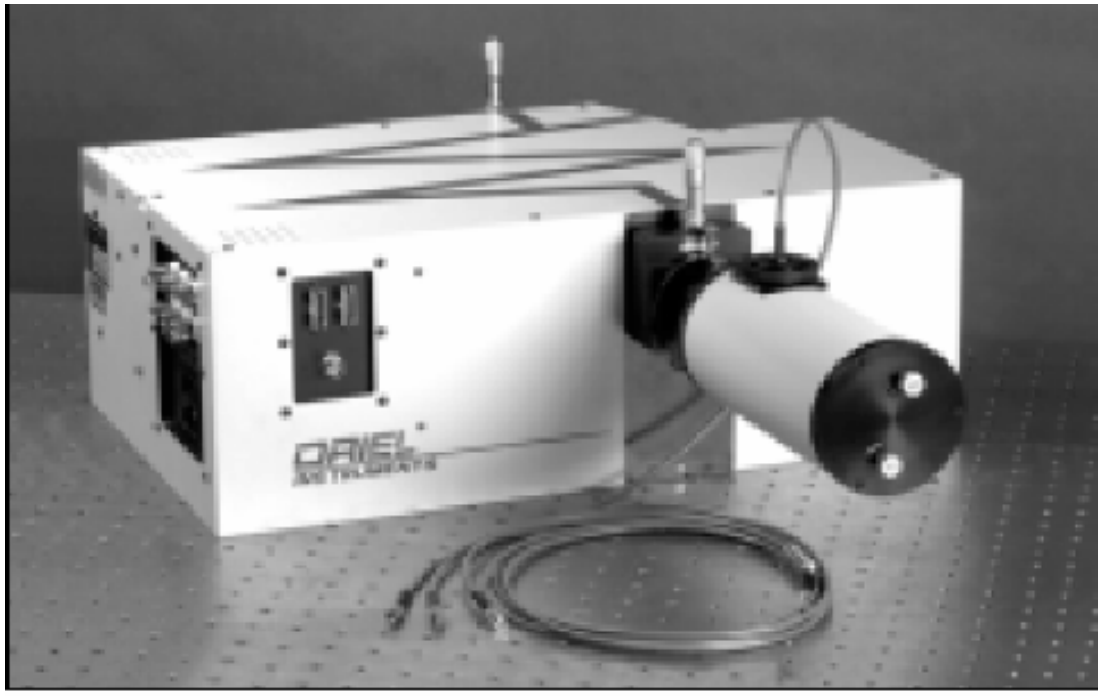
HPD (DEP)
extremely good p.e. resolution





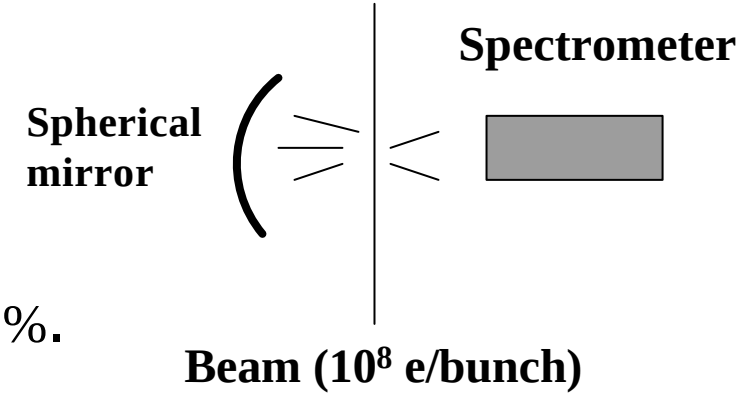
Detectors

L.O.T. Oriel
Spectrometer MS257
Focal length 25.7 cm
? ? = 0.1 nm



Andor CCD DV 420
1024 ×256 active pixels
Dark Current:
3.6 e_{CCD}/pixel/hr at -80^{o}C

Acceptance with spherical:
~ 500 e_{CCD} / bunch



In few minutes we expect to reach a
% statistical accuracy with back/sign ? 1%.

CONCLUSIONS

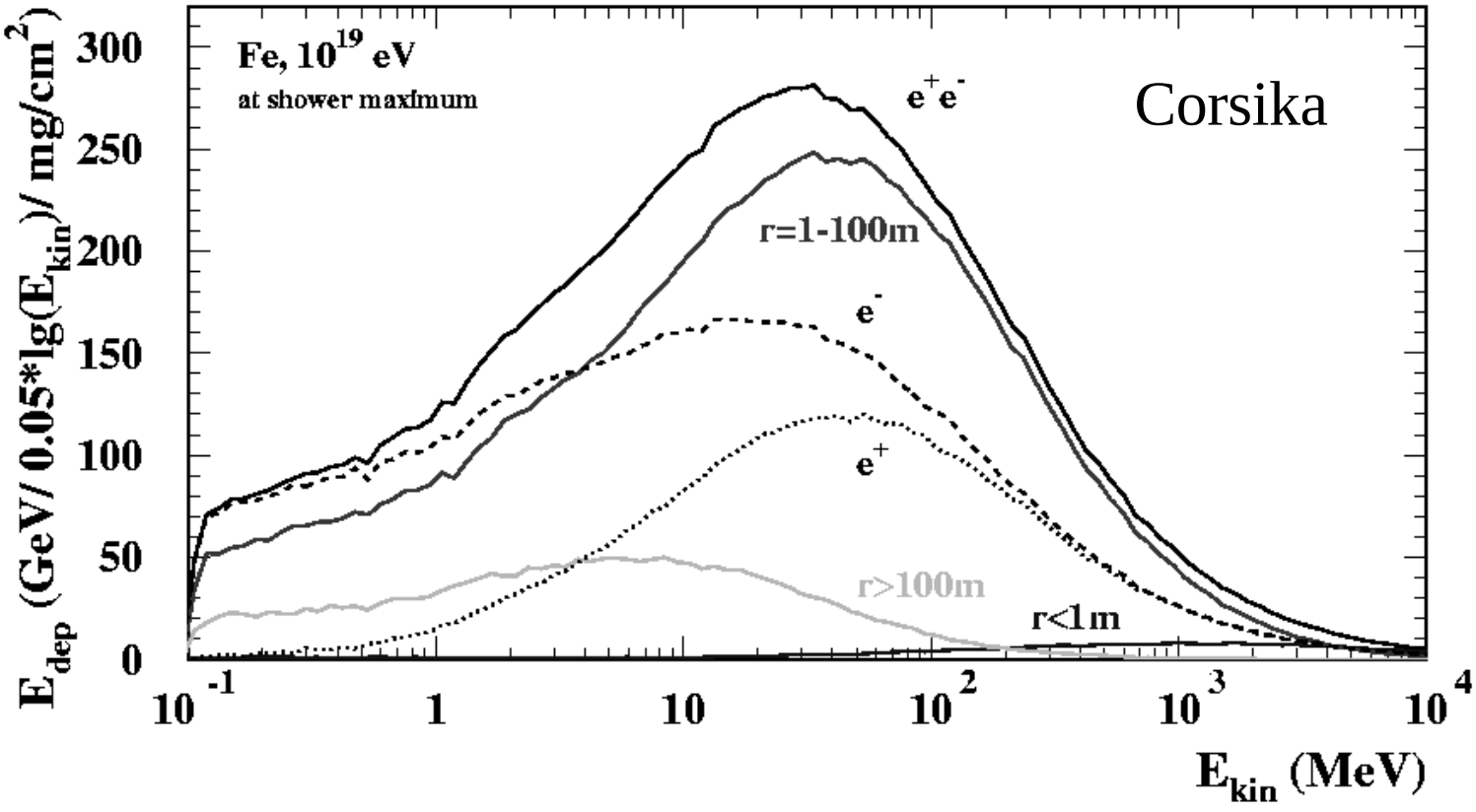
Test beams have shown the feasibility of the AIRFLY physics program:

- ? New method for the absolute measurement (few % precision)
- ? Very precise energy scan (50-750 MeV)
- ? pressure, temperature and gas dependences

The final detector as been defined and it will be tested at the end of June.

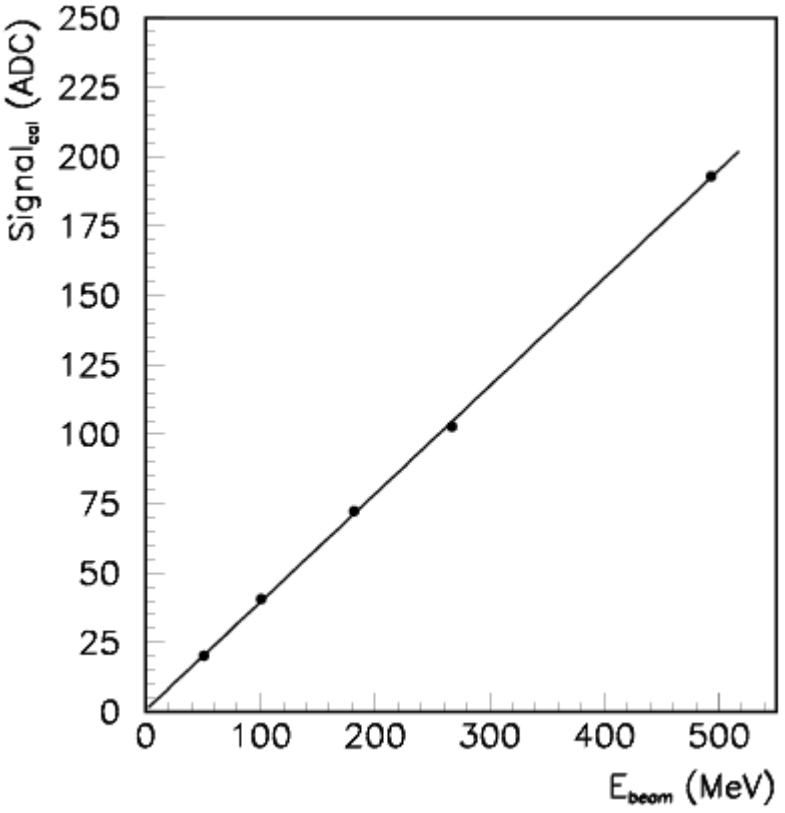
We expect to have preliminary results with the final setup by the end of the year.

Most of the energy deposited by 1 – few hundreds MeV electrons/positrons

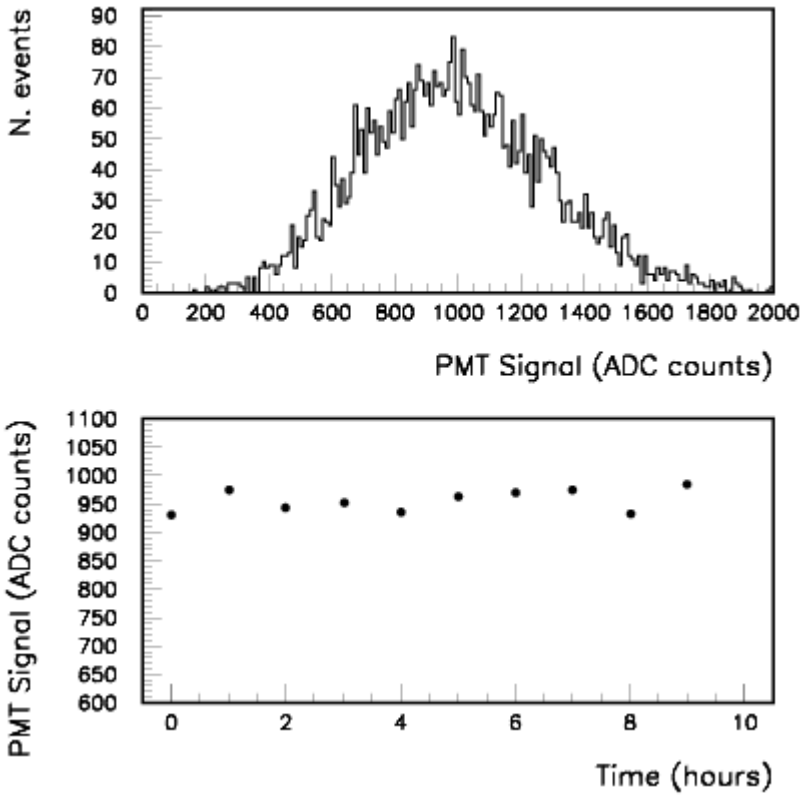


Systematic Uncertainties

Calorimeter linearity better than 2%

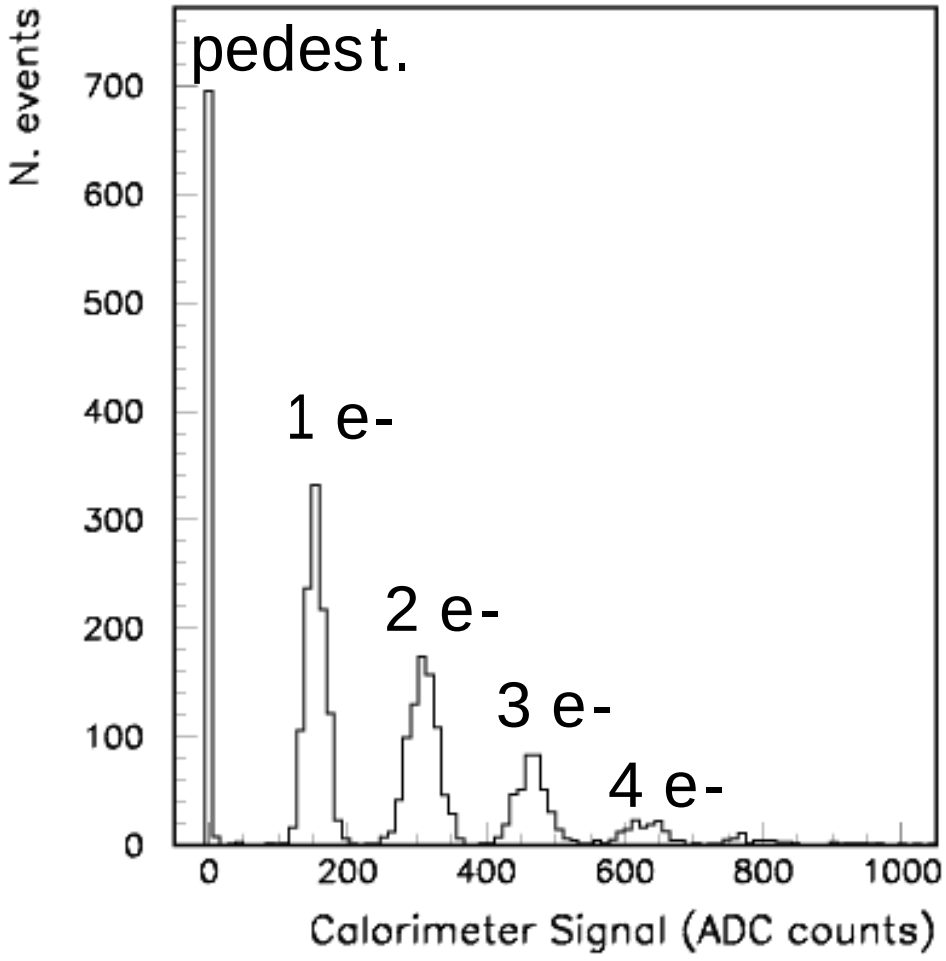


PMT monitored with Xe flash lamp; maximum variations during scan ±3%

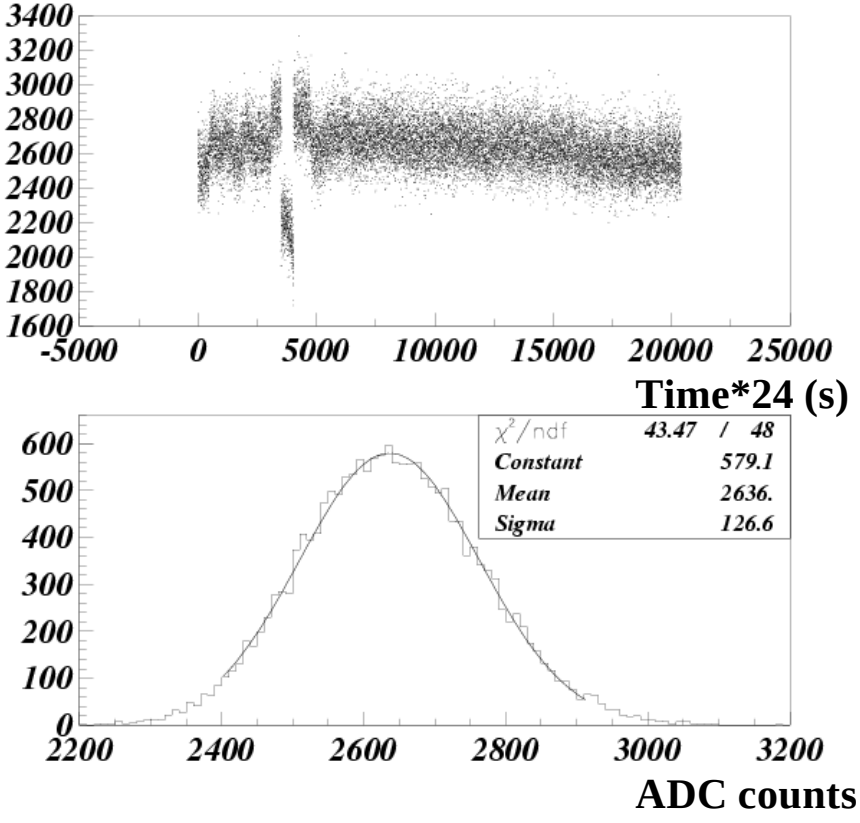


Beam Monitoring with the Calorimeter

Calorimeter counts single electrons



The calorimeter is used for absolute and relative beam intensity measurement (<1000 e-/bunch)



Humidity Control System

✍Simple system. Relative humidity from 0 to 90%. Working.