

Air Light 03, 11-14 December 2003, Bad Liebenzell

Status and prospects of the AIRFLY experiment

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Fluorescence yield in air

Excitation of the nitrogen molecules and their radiative deexcitation. Collisional quenching

We must measure:

- Electron energy dependence

$\sim dE/dx$

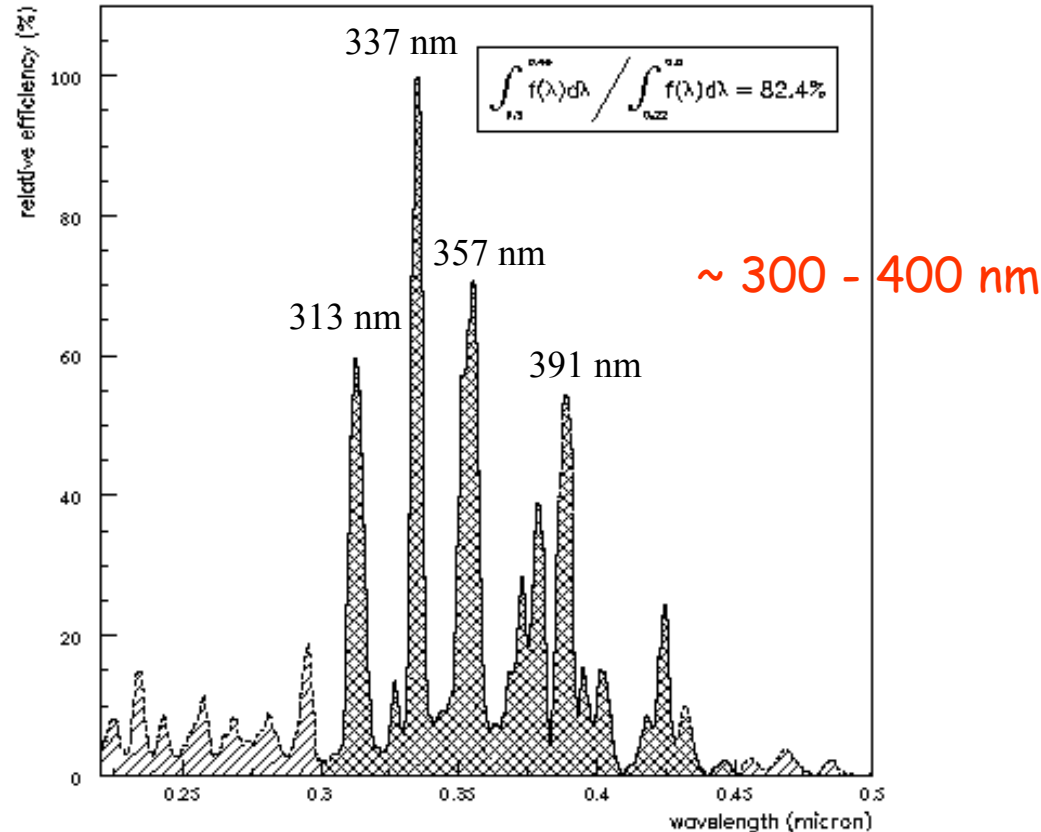
- p and T, gas dependence

Yield vs altitude

Argon, O₂ quenching,
water vapour over the ocean

- λ dependence

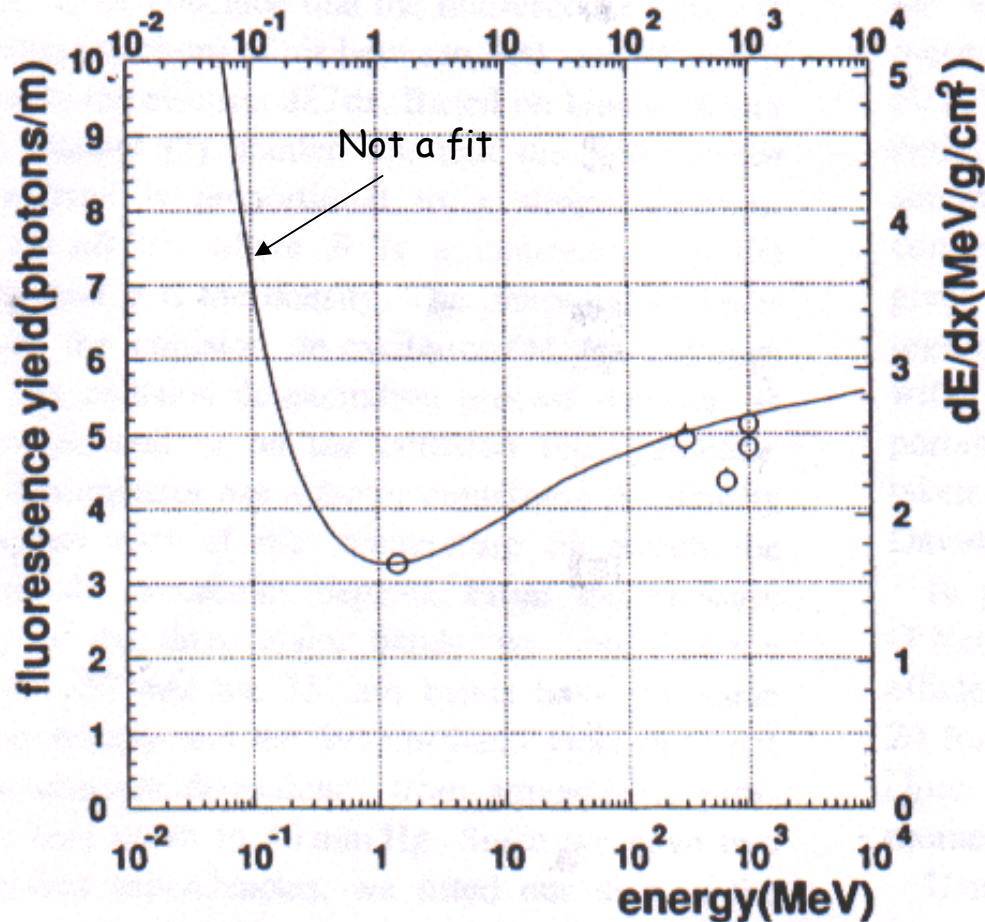
Atmospheric transmission,
Rayleigh scattering $\sim 1/\lambda^4$



Bunner, Ph.D Thesis
Cornell Univ. 1967

Measurements with α
and 50 keV electrons
totally absorbed in air

Electron energy dependence



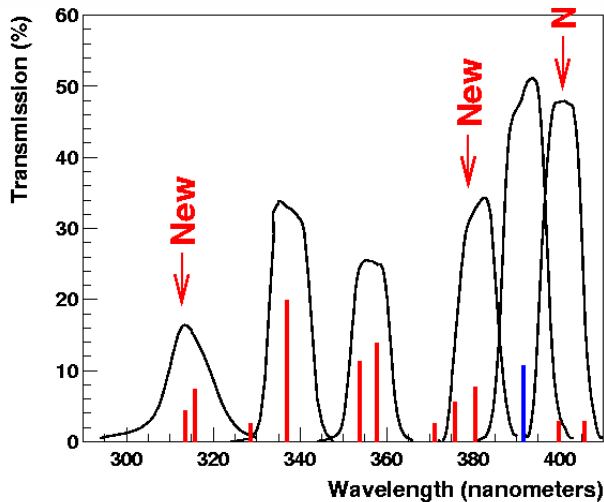
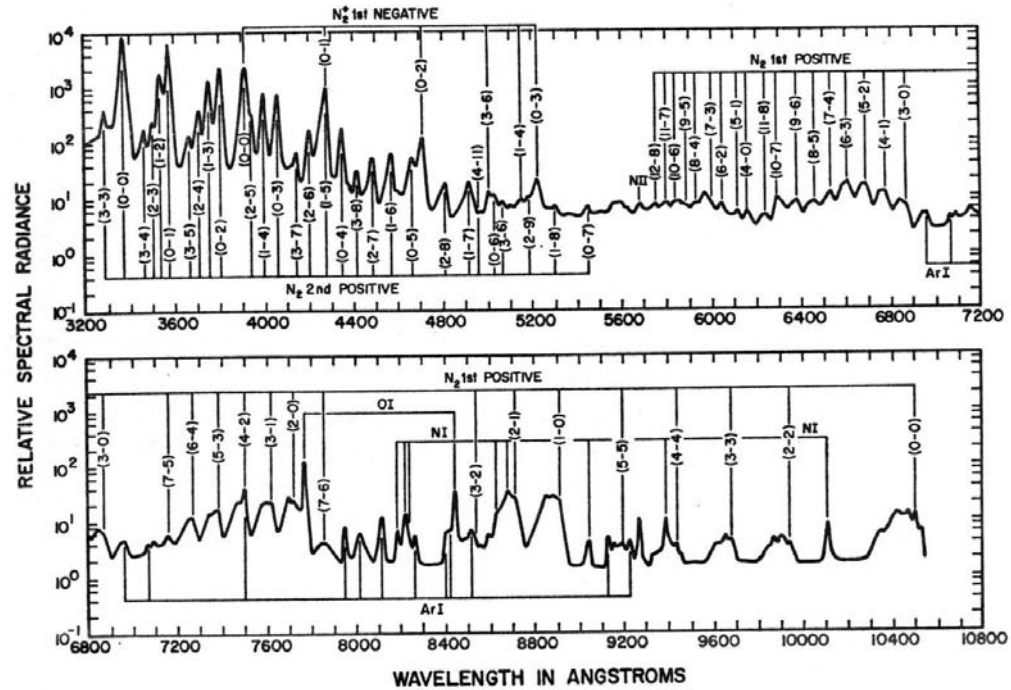
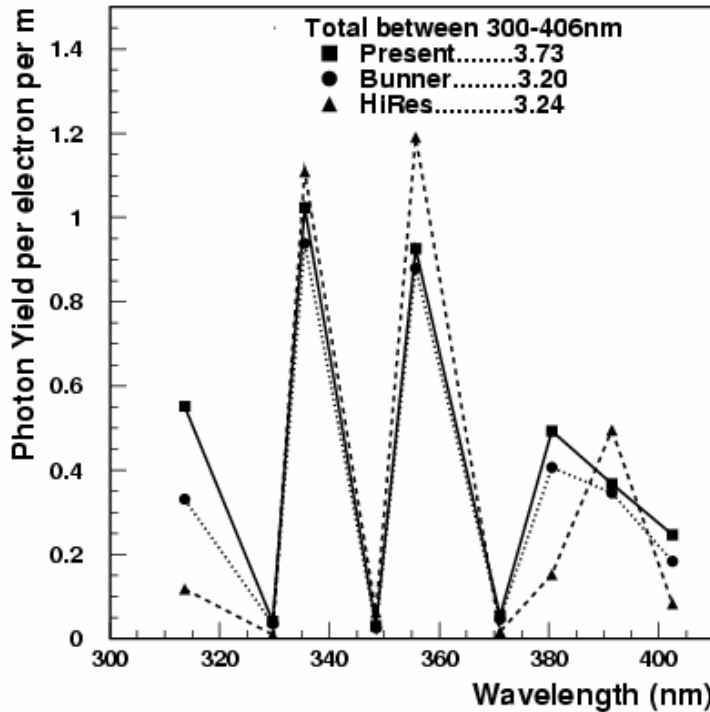
Kakimoto et al.,
NIM (1996)

- ~ 2 experimental points:
- 1.4 MeV ⁹⁰Sr
- around 1 GeV e-beam

NOTE: 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

Fluorescence yield spectrum

Air



Nagano et al.,
astro-ph/0303193
 β source

Davidson and
O'Neil (1964)

NOTE: the only existing
detailed spectrum (50 keV
electrons stopping in air at
600 torr, 1.8 nm resolution)

~ 10 nm filters

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

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AIRFLY

- Electron energy dependence
 - ^{90}Sr (2.3 MeV) and ^{106}Ru (3.5 MeV) 10 mCi sources, electron and positron beam at the BTF of the L.N.F. in the range 50-750 MeV (in particular @80MeV E_{crit} air)
- p and T, gas dependence
 - Cylindrical chamber with p (1 mb - 1 b) and T (220-300 K) control, gas system with N_2 , O_2 and Ar mixing, artificial dry "air", water vapor control
- Wavelength dependence
 - low noise PMT + interference filters, calibrated light source, spectrophotometer

The DAΦNE Beam Test Facility



Electrons production scheme

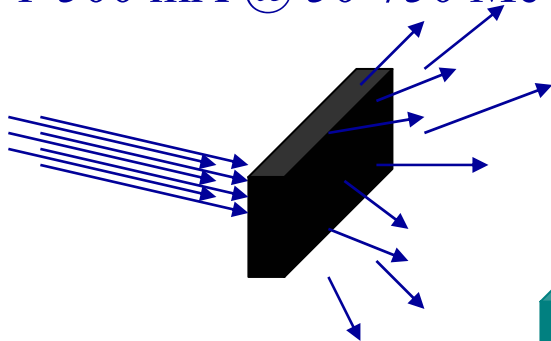
Pulse Duration 1-10 ns

Max. repetition rate 50 Hz

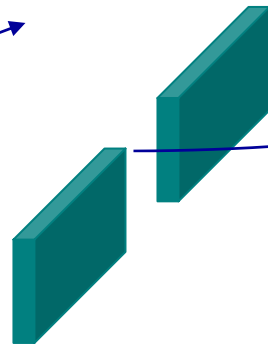
LINAC Beam

(Max. 10^{10} particles/bunch)

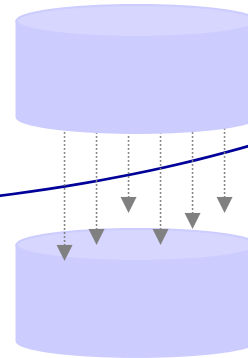
1-500 mA @ 50-750 MeV



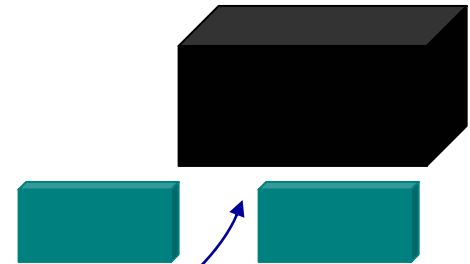
tunable Cu target:
1.7, 2.0, 2.3 X_0



collimators



45° magnet



BTF HALL
calorimeter

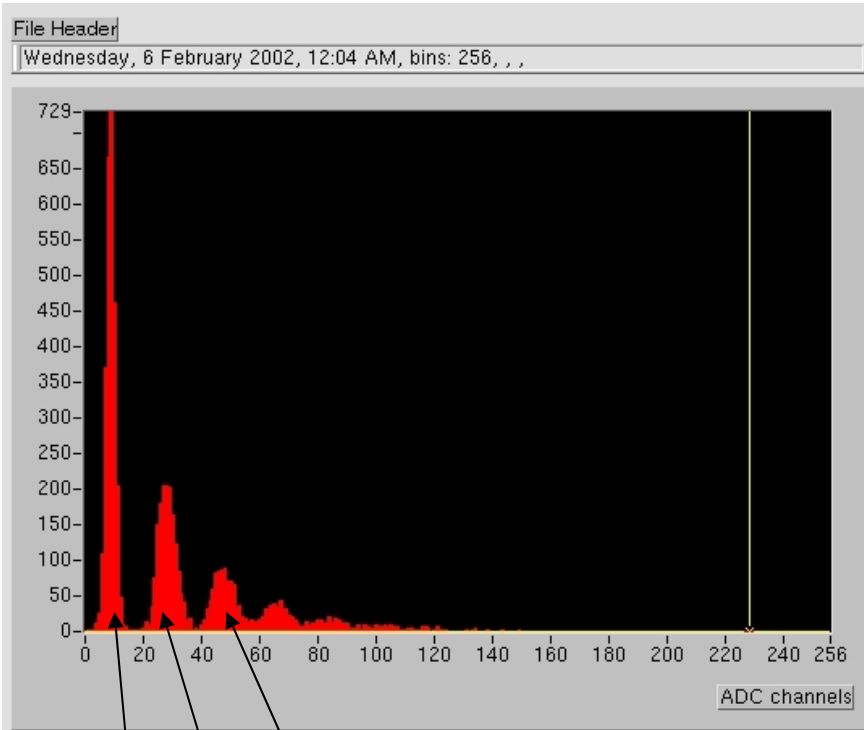
50-750 MeV beam

1% energy spread

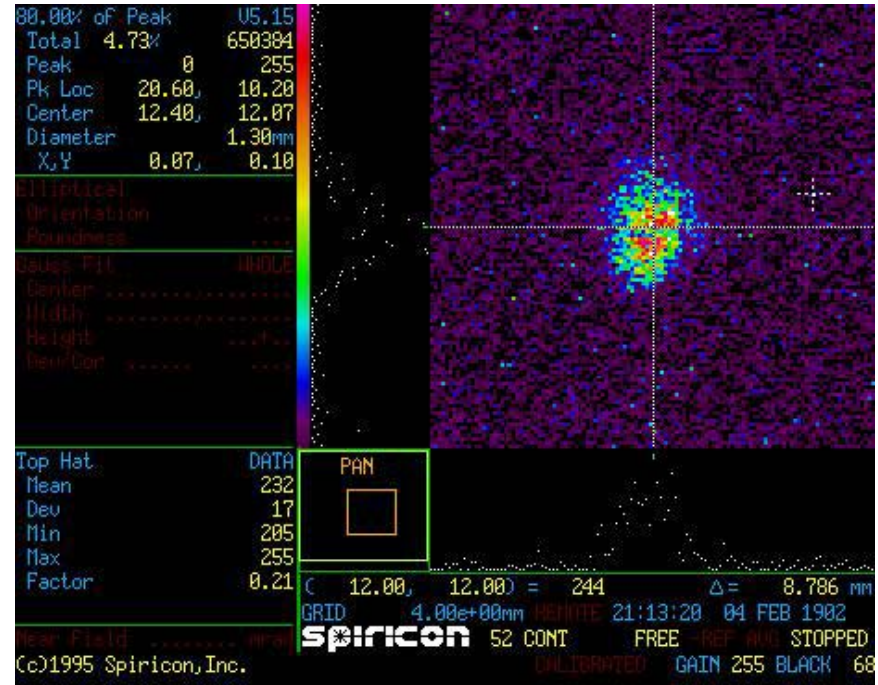
The Beam Test Facility at DAΦNE

~ single electron/bunch

Beam spot ~ 1 mm diameter

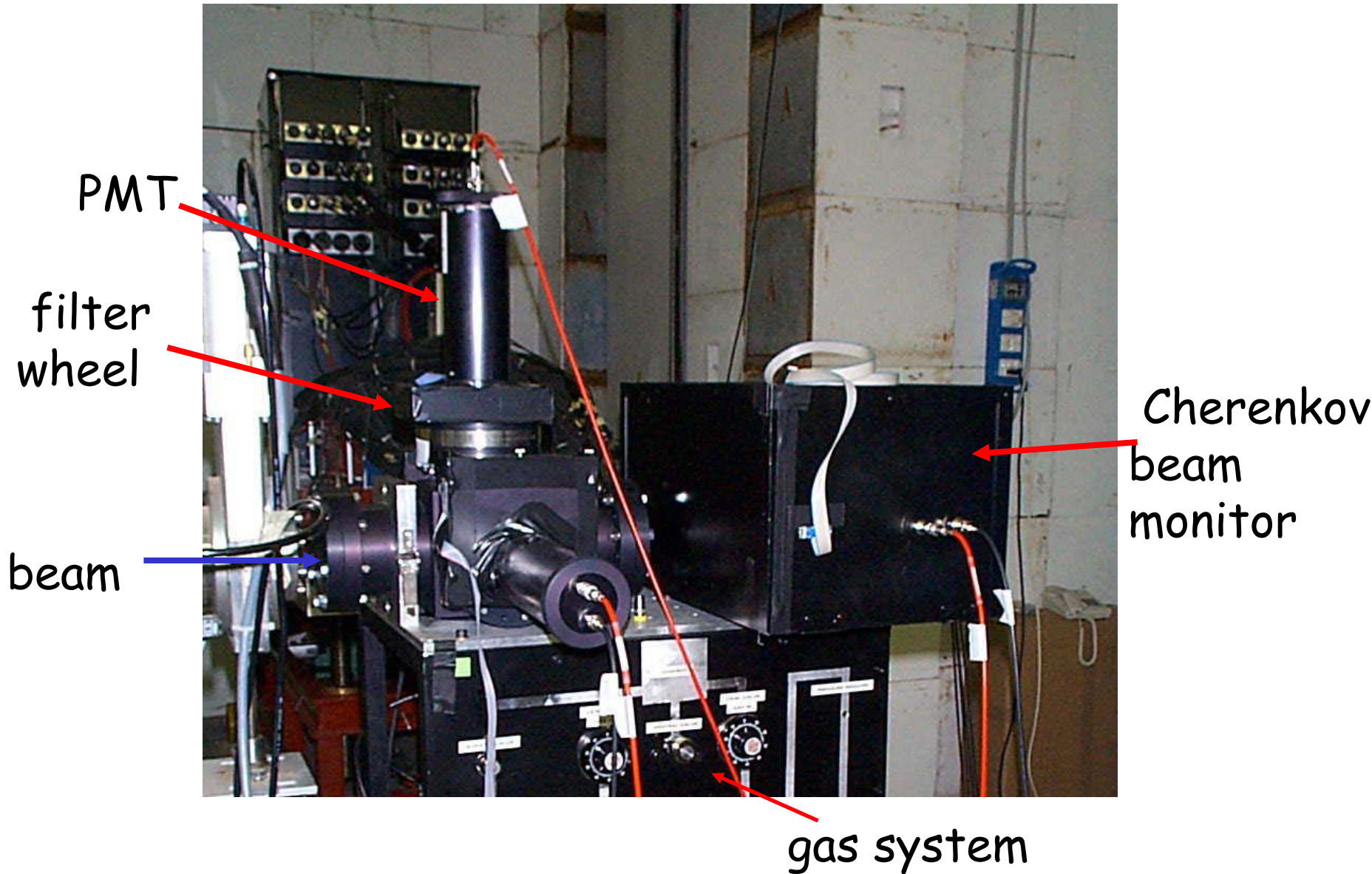


energy measured
at the BTF calorimeter

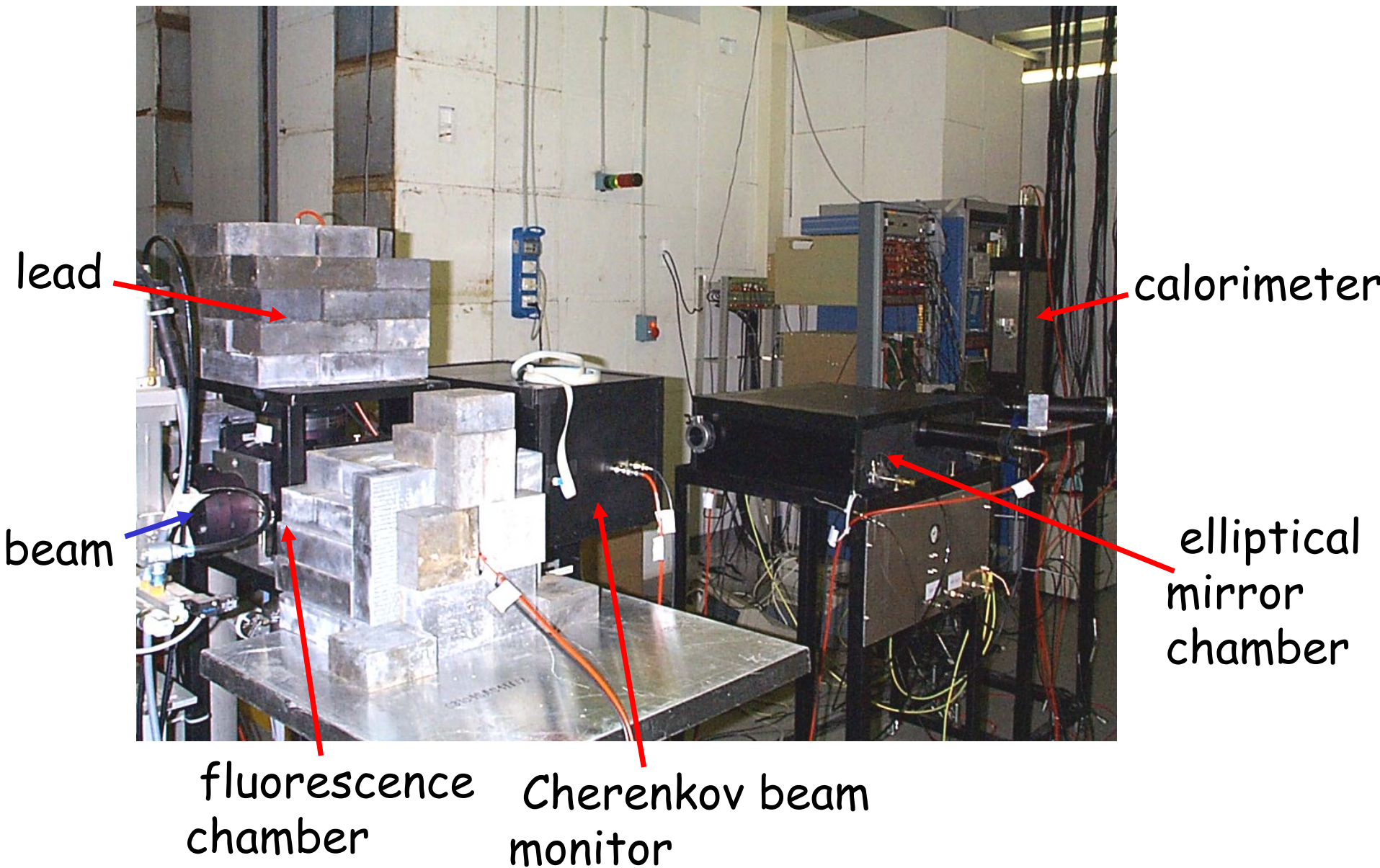


Possible to defocus beam to
test density effect

AIRFLY fluorescence chamber at the BTF

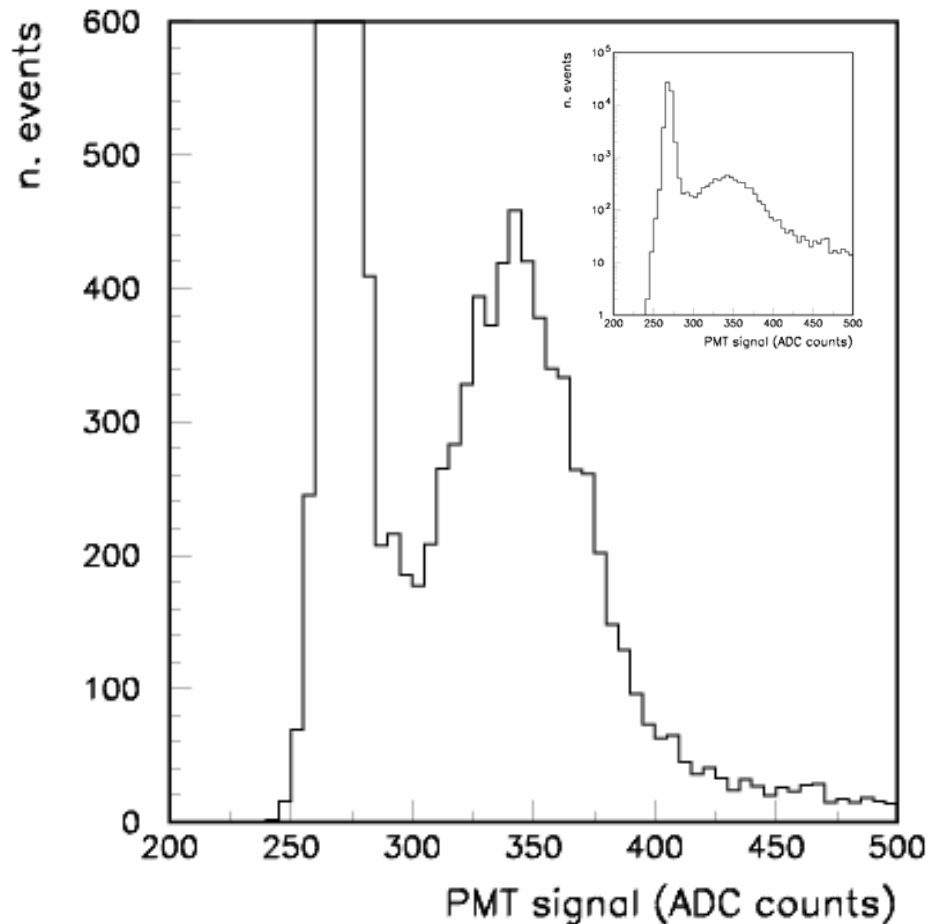


AIRFLY at the BTF

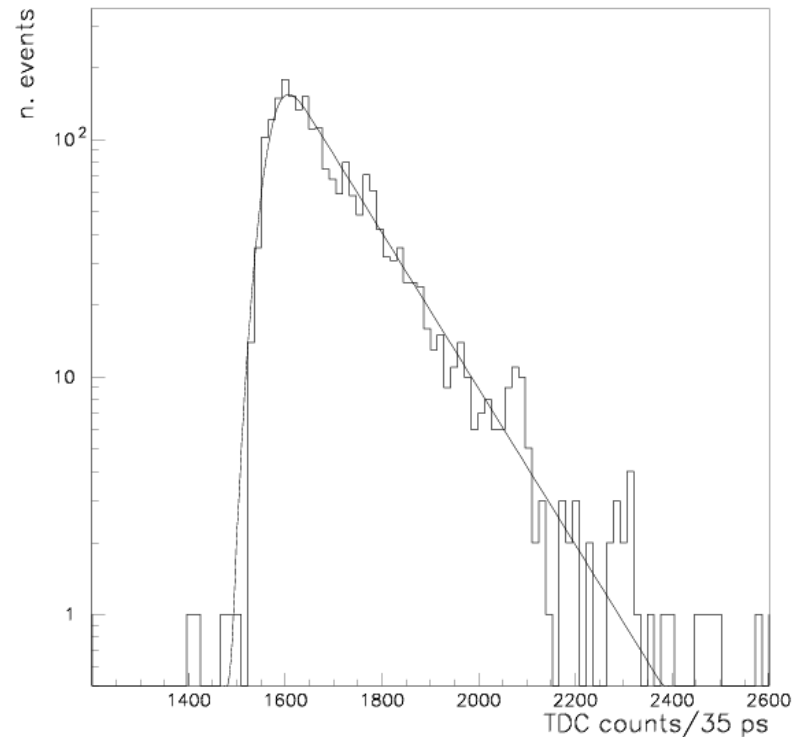


First measurements at the test beam

Single p.e. counting



Fluorescence Lifetime
 ≈ 5 ns at 340 mbar N₂



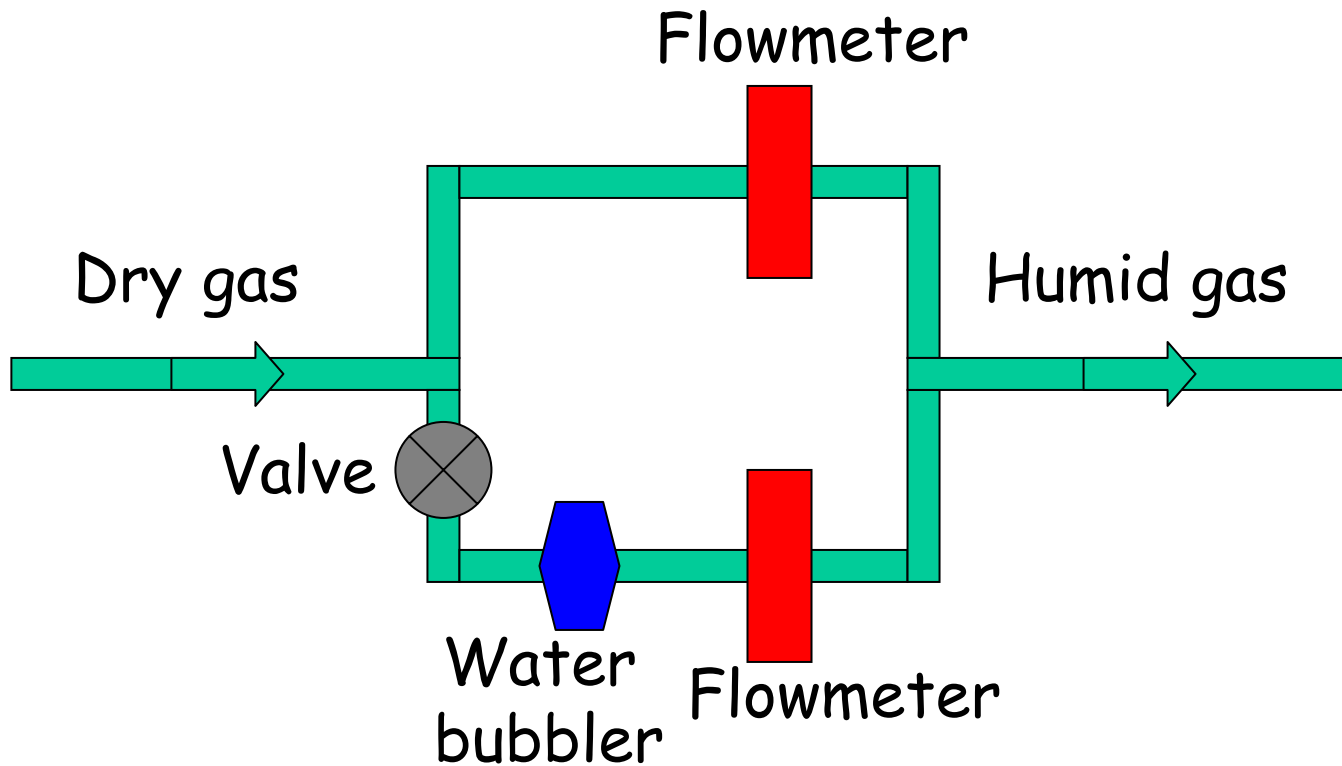
Beam multiplicity 200-1000 e⁻/bunch , ≈ 1 ns width

Main goals/achievements in 2003

- Operation of test fluorescence chamber with nitrogen and dry air. Remote control of gas and pressure. Filters characterization (**S. Klepser**). Humidity control and sensors (**J. Ridky**). DAQ.
- Improved light collection (**M. Hrabovski**).
- Understanding and optimization of beam associated background.
- Tests of beam monitoring detectors (**M. Bohacova**).
- Feasibility of measurement of energy dependence of fluorescence yield.
- Test of new method for absolute fluorescence yield measurement (**V. Verzi**)

Humidity control system

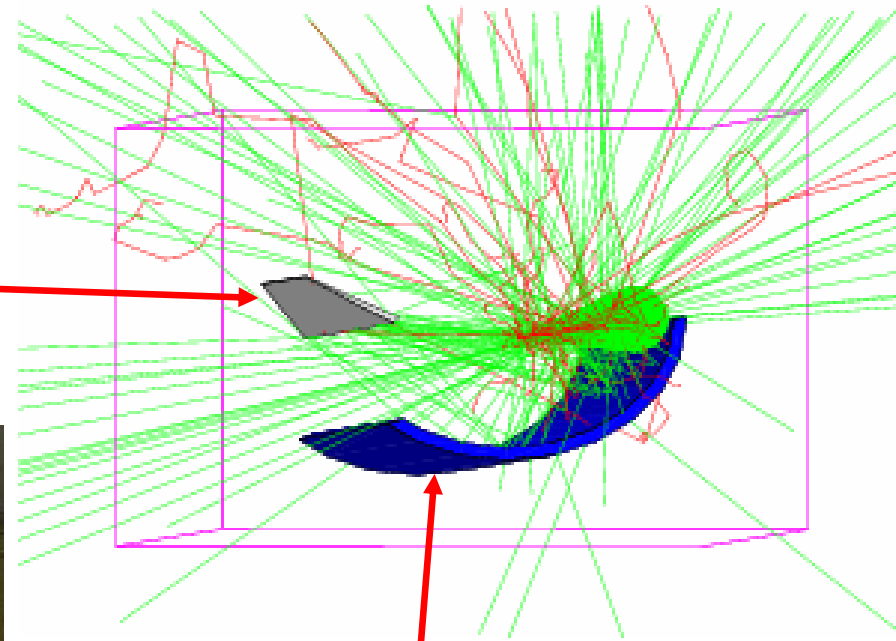
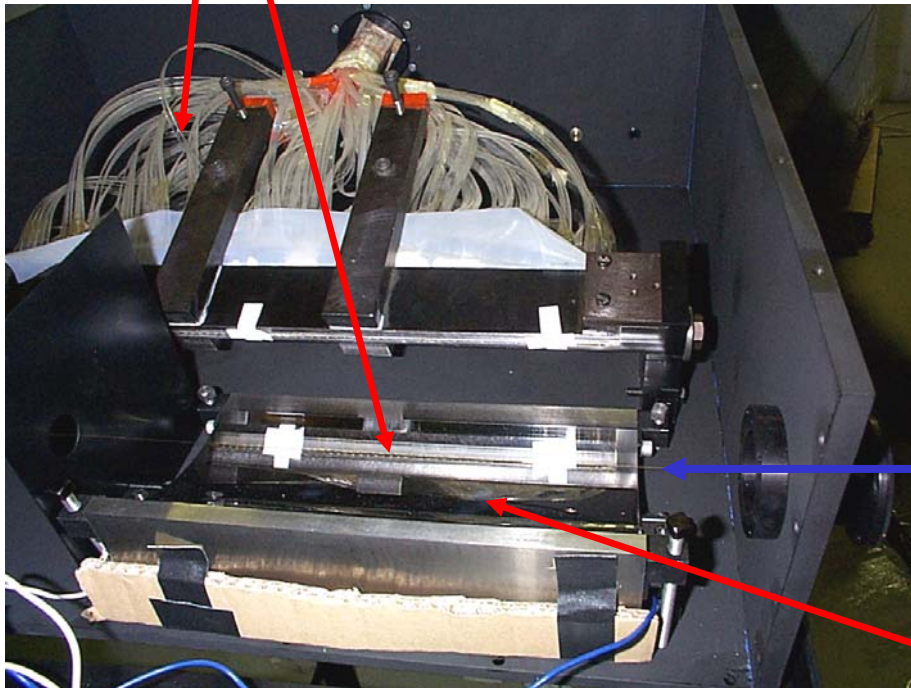
- Simple system. Relative humidity from 0 to 90%. Working.



The elliptical mirror chamber

Light
collecting
fibers

To PMT



beam

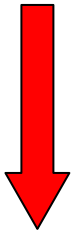
Significantly
increased
acceptance
(factor 10)

Elliptical mirror

Beam associated background

- We achieved a significant improvement in the background thanks to beam and detector shielding.

≈20% bkg. in N₂ with UG6 filter (March 2003)



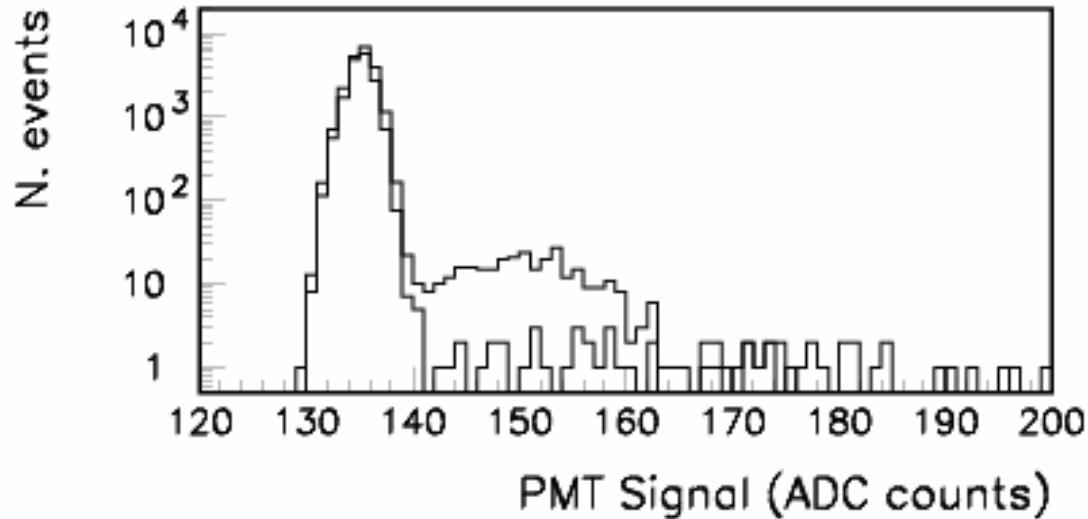
≈5% bkg in air with 337 nm filter (December 2003)

For comparison: Nagano source exp., 17% bkg. in air with 337 nm filter

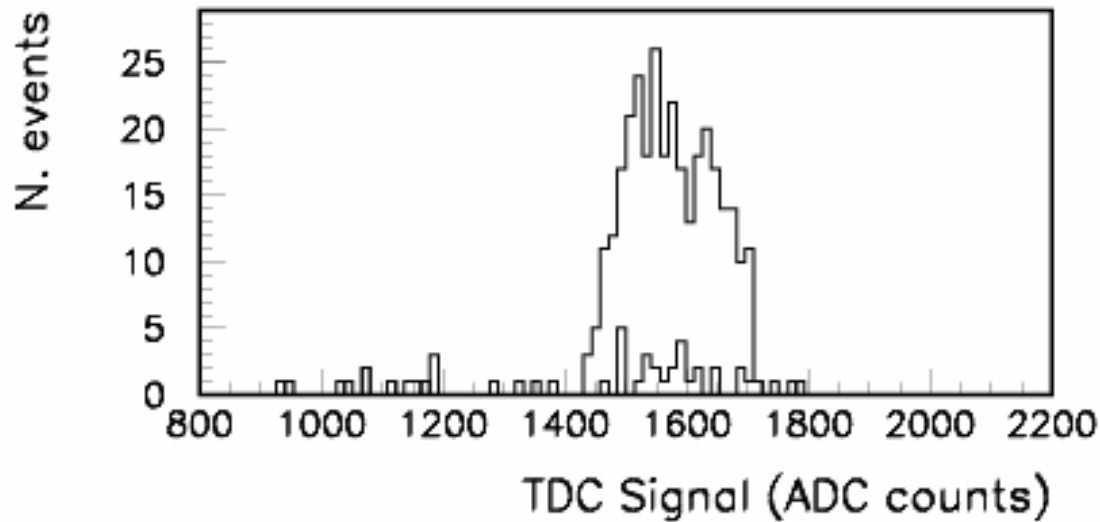
- Further reduction to 1% level is expected (1 inch -> 2 inches optics and/or light collection mirror)

Important for high precision measurement

Signal vs background (600 e-/bunch)



Signal in air with 337 nm filter was around 1% of all triggers

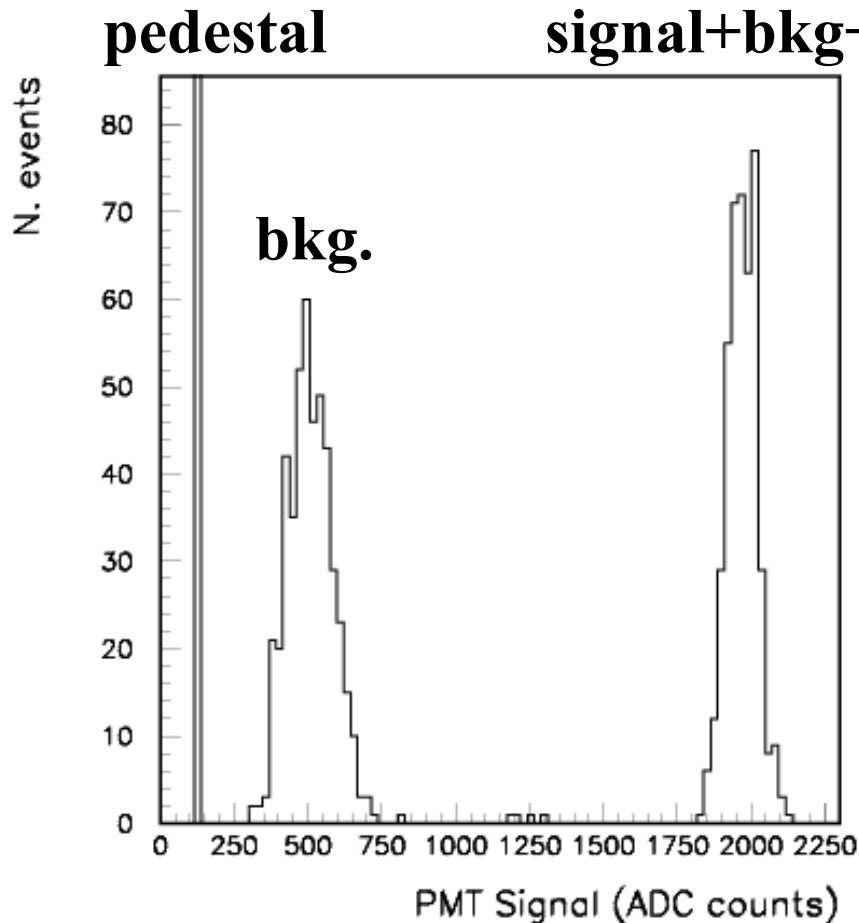


Background measured by closing the PMT shutter

← 10 ns →

Signal vs background (10^8 e-/bunch)

First tests with high intensity beam were performed



25% bkg. with 337 nm filter
in air

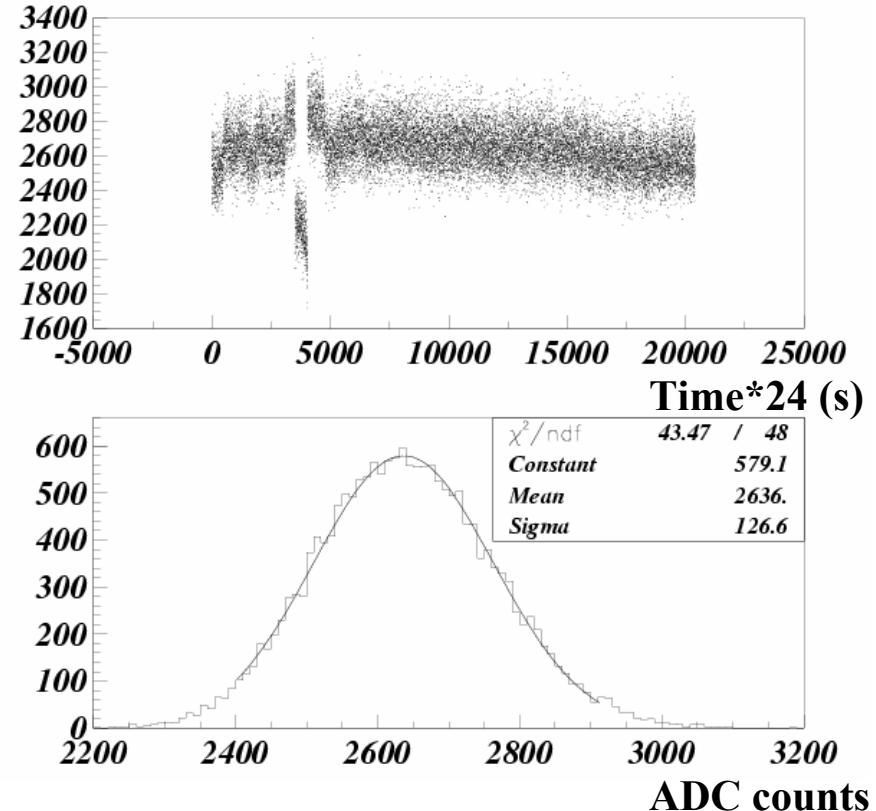
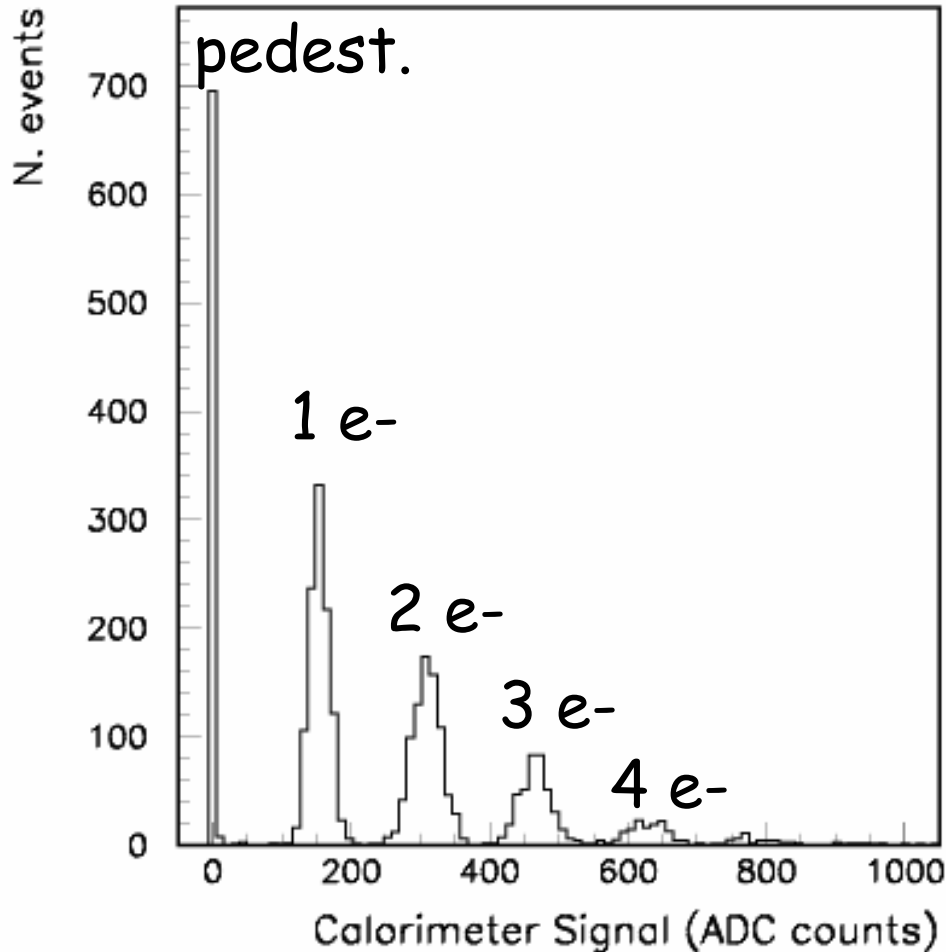
improvements by better
shielding+acceptance

Lower bkg. expected with
CCD (small area detector) for
the spectrum measurement
(**S. Petrer**)

Beam monitoring with the calorimeter

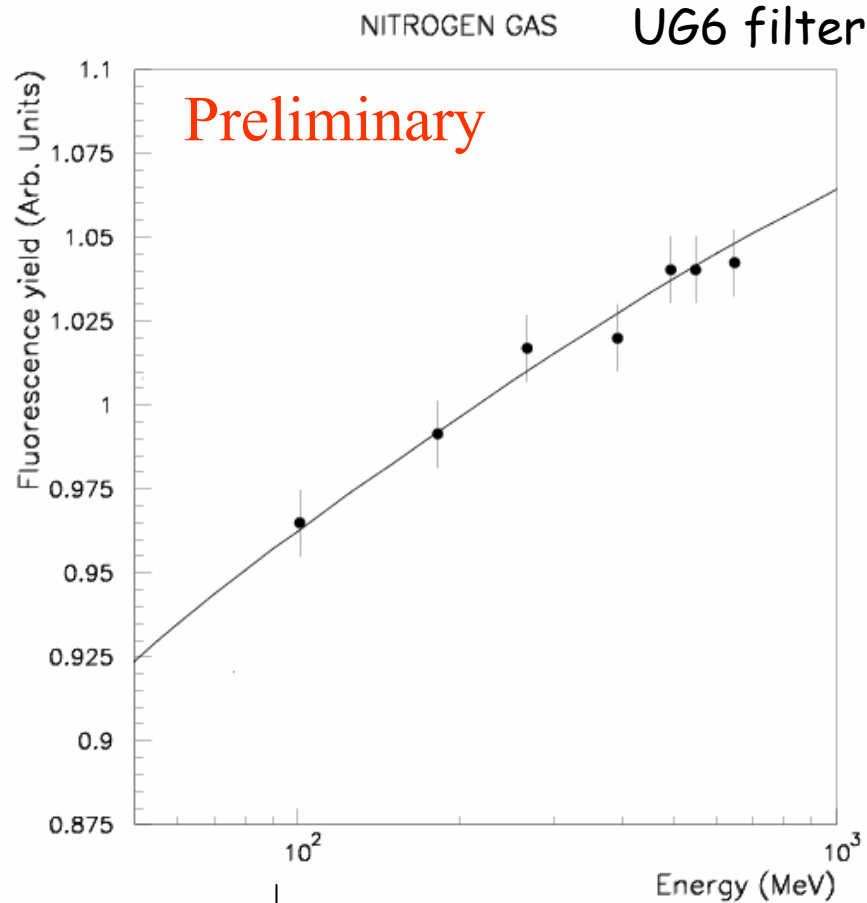
Calorimeter counts
single electrons

The calorimeter is
used for absolute and
relative beam intensity
measurement
($<1000 e^-/\text{bunch}$)

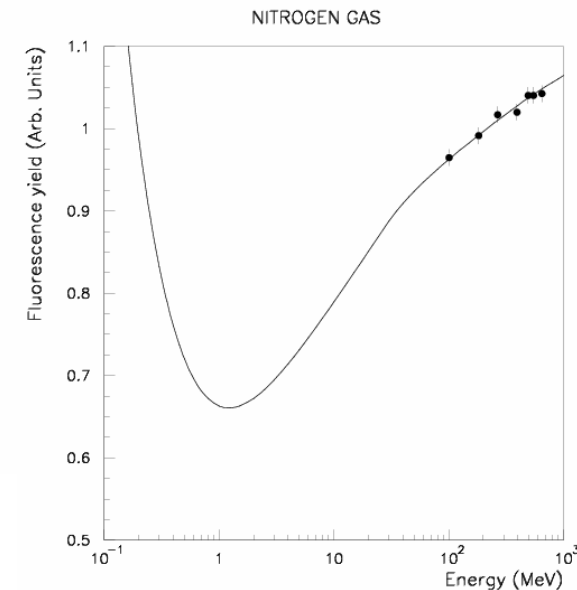


Energy dependence of fluorescence yield

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



The scan was performed several times with consistent results.

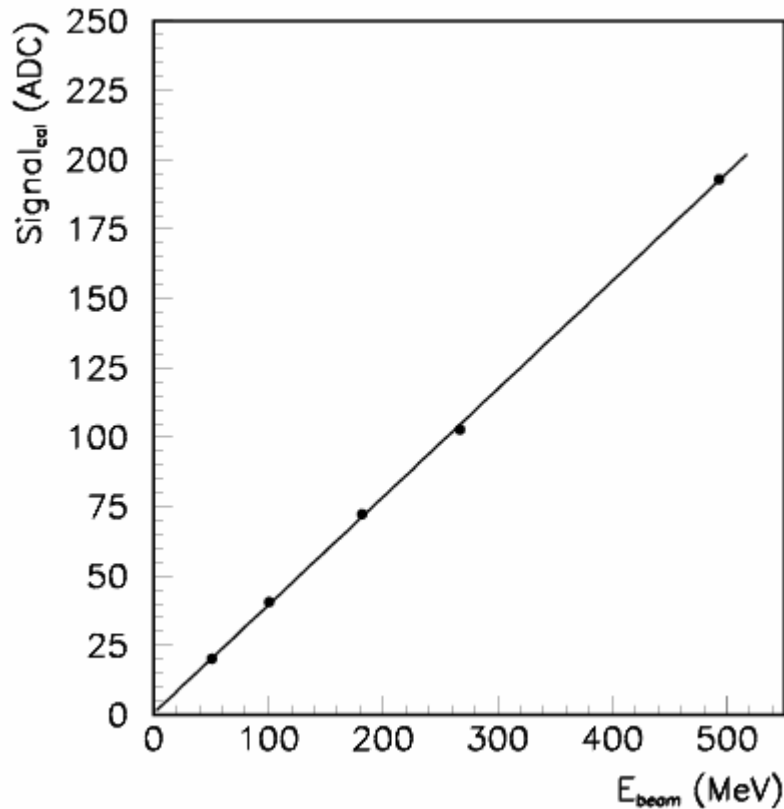


Limited by multiple scattering on 1.5 mm thick exit Al window. The scan went down to 50 MeV.

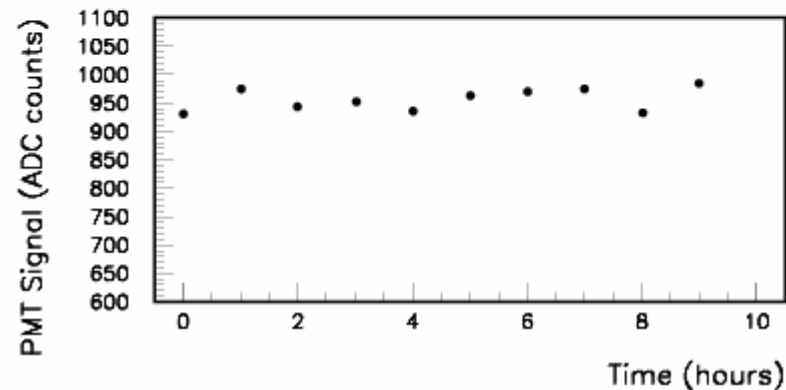
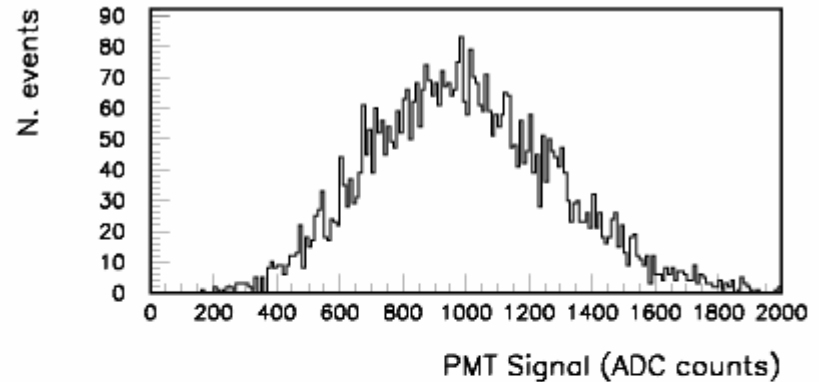
Positrons (493 MeV) gave same yield within 3%

Systematic uncertainties

Calorimeter
linearity better
than 2%



PMT monitored with
Xe flash lamp;
maximum variations
during scan $\pm 3\%$



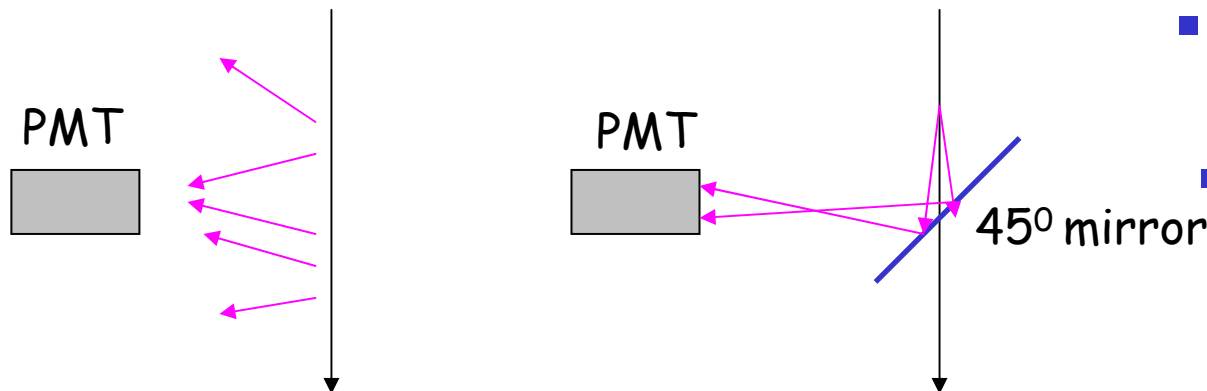
New method for absolute measurement of fluorescence yield

- IDEA: normalize to well known process (cherenkov emission) to cancel detector systematics

$$N_{337}(\text{fluor.}) = \text{FLY} \times \text{Geom}_{\text{fluor}} \times T_{\text{filter}} \times \text{QE}_{337} \times N_{\text{electr.}}$$

measured known MC Cancel! relative meas.

$$N_{337}(\text{cher.}) = \text{CHY} \times \text{Geom}_{\text{cher}} \times T_{\text{filter}} \times \text{QE}_{337} \times N_{\text{electr.}}$$



- Systematic error potentially $\leq 5\%$
- First tests very encouraging!

Instruments for 2004 run

- 40 mm diam. HPD -> extremely good single p.e. resolution, smaller background.
- 4 Hamamatsu H7195PX PMTs absolutely calibrated.
- 2 inches diam. high quality narrow band filters
- Hamamatsu calibrated Xenon lamp for absolute/relative calibration (NIST standard).
- Oriel spectrometer+CCD.
- 0.5 mm thick Be windows.

AIRFLY program in 2004

- Finalize apparatus design in January 2004.
- Absolute measurement of fluorescence yield at 337 nm. Fluorescence/cherenkov very promising. Goal $\leq 5\%$ systematic error.
- Relative measurement of the spectrum with high intensity beam (10^8 e-/bunch) and spectrometer+CCD.
- Measurement of energy dependence of fluorescence yield in air down to 50 MeV \rightarrow 0.5 mm thick Be exit window. Complement with ^{90}Sr low energy point.
- Study of pressure, humidity, temperature dependence. All relative measurements.