GSPC-Meeting, Garching, December 10-11 2009

Characterization of CF_4 primary scintillation

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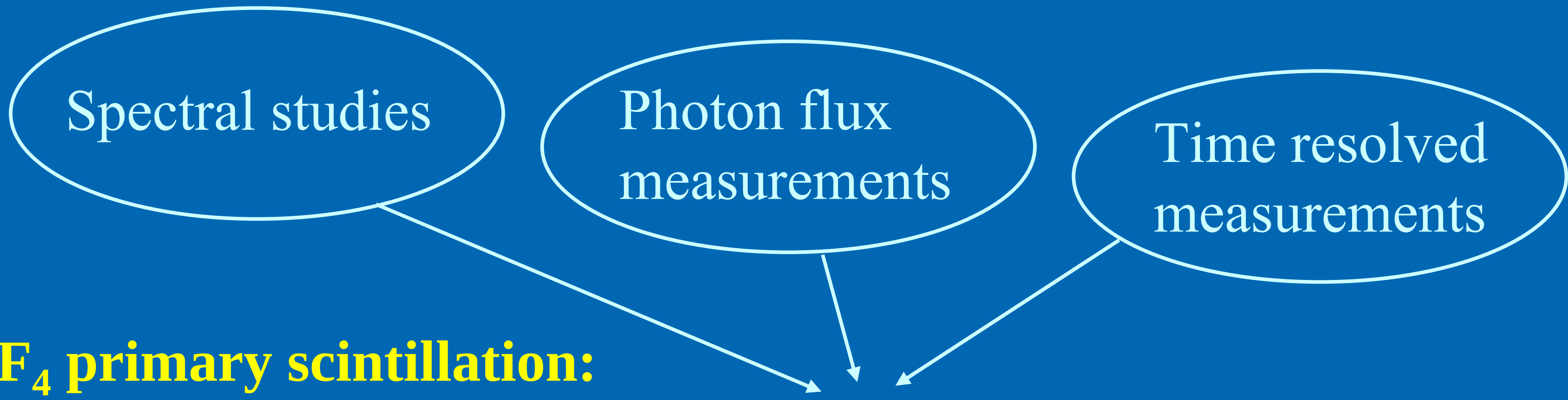
Francisco Fraga

What, why and how?



CF_4 primary scintillation:

Light emission and photon yield	√
Effect of applied electric field	√
Effect of He admixture	√
Quenching effects (gas aging)	+

Content

Spectral studies

+spectrometer calibration

Absolute photon flux measurements

+detection efficiency vs. wavelength

Alpha-source characterization

Photon yield

+cross-tests

Time resolved measurements

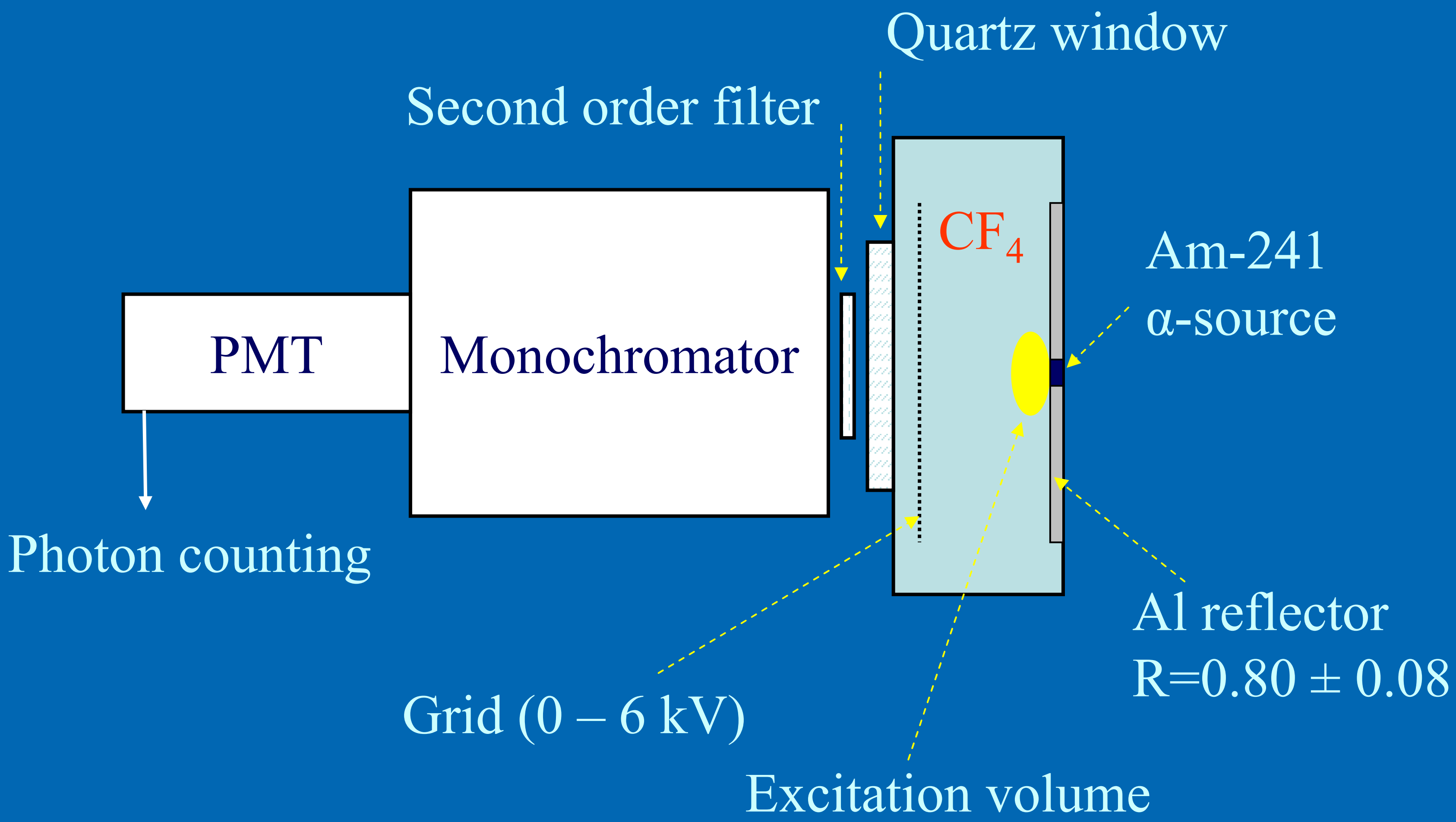
Effect of electric field on CF_4 primary scintillation

CF_4 – He mixtures

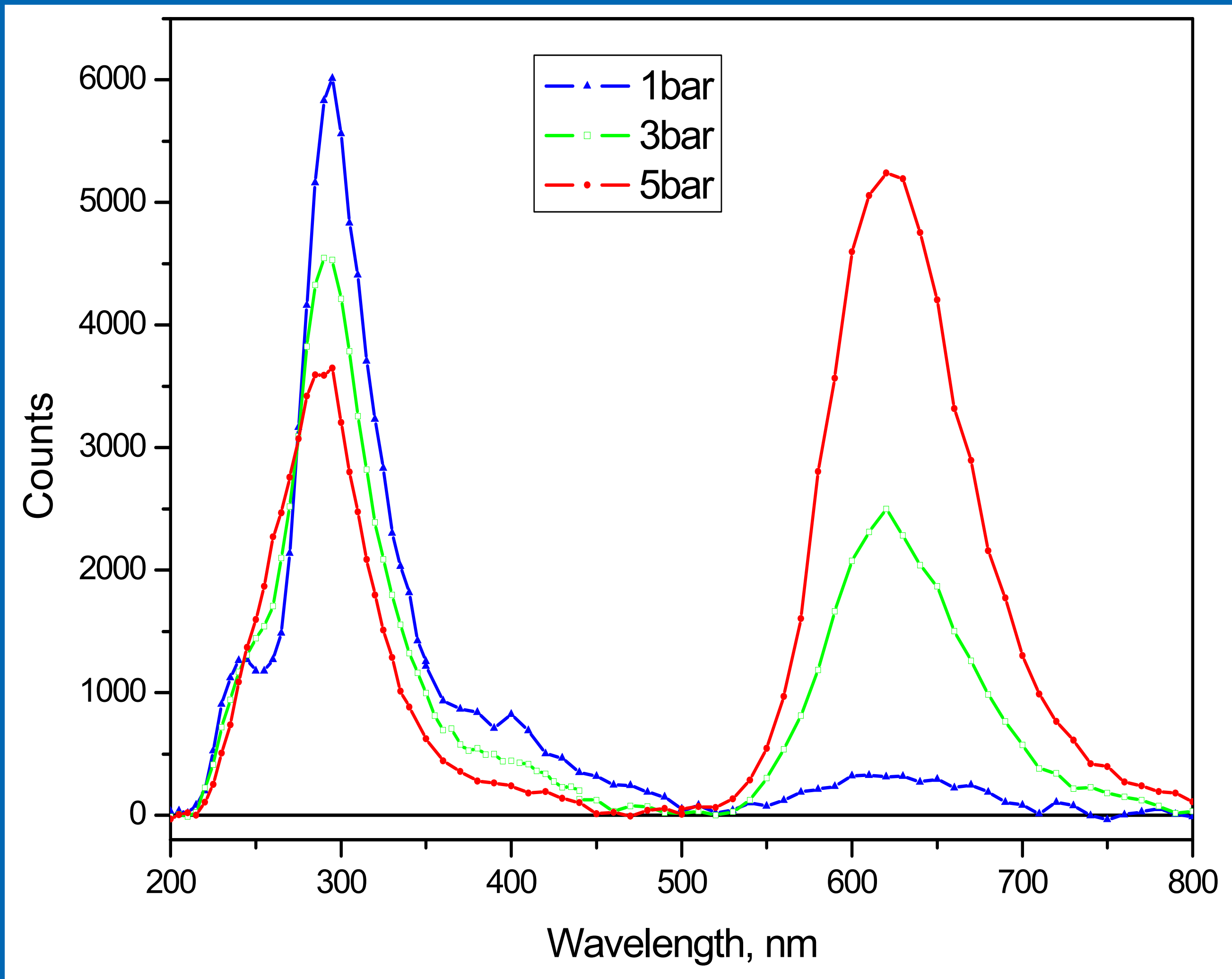
Gas aging and quenching by N_2

Spectral studies

Spectral studies: Setup



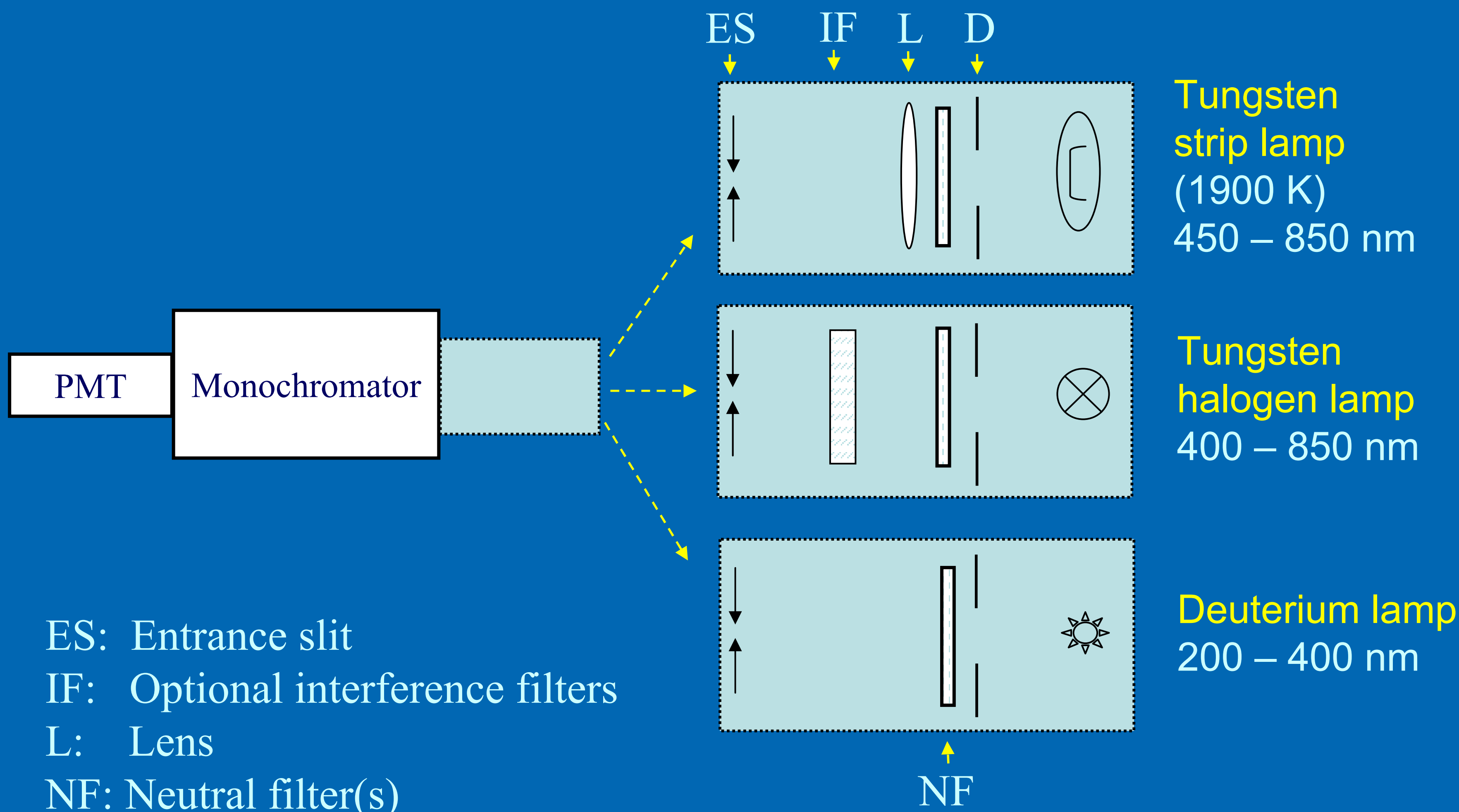
CF_4 primary scintillation: Raw spectra



Spectra have to be corrected for:

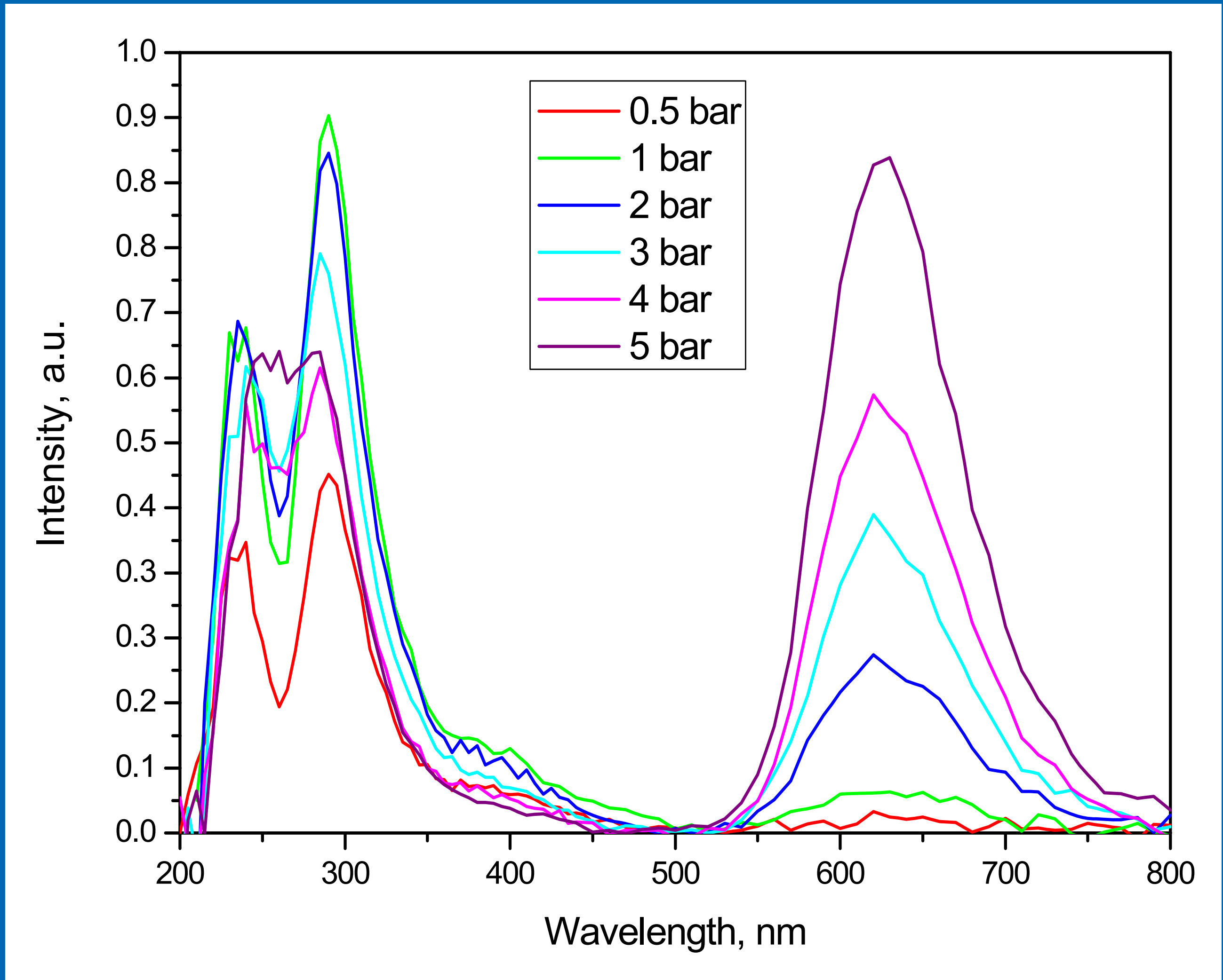
1) Response of the monochromator and PMT
2) Geometrical factor of the detection
3) Gas aging

Monochromator+PMT response measurements

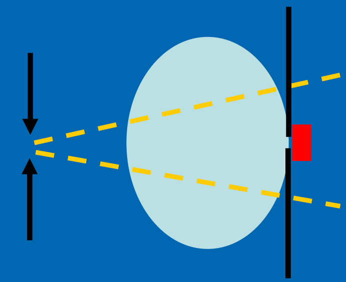


ES: Entrance slit
IF: Optional interference filters
L: Lens
NF: Neutral filter(s)
D: Diaphragm

Spectra corrected for the instrumental response



Spectra from different pressures are not to scale!

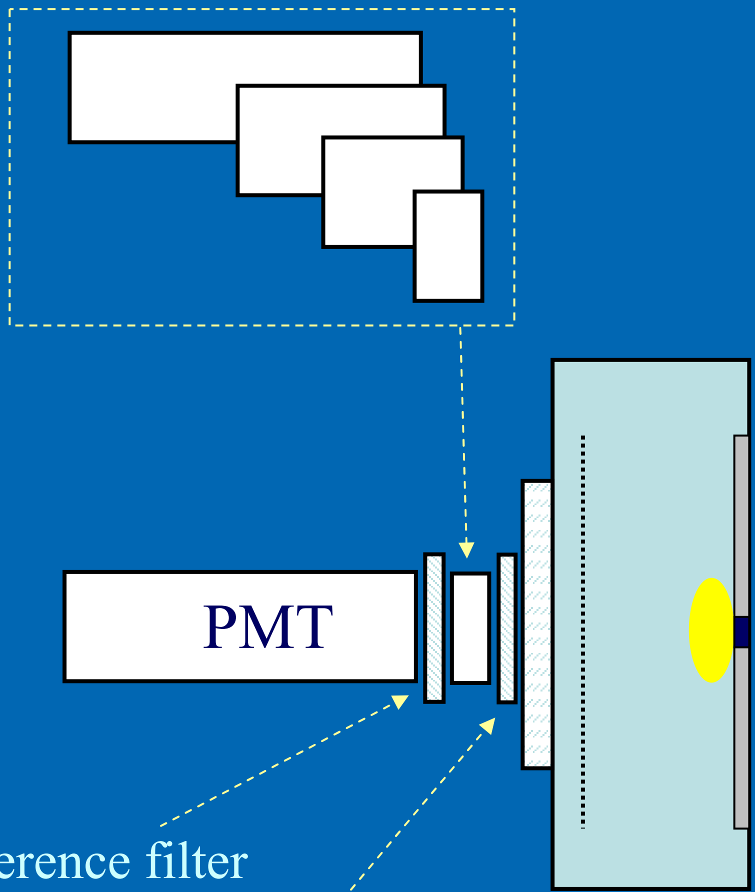


Need direct photon flux measurements

Absolute photon flux measurements

Absolute photon flux measurements: setup

Extension tubes



Extension tubes:
PMT-to-source distance is adjustable from 80 to 300 mm

Light source is a half-sphere, radius:
~3 mm at 5 bar
~13 mm at 1 bar
~26 mm at 0.5 bar

Optional interference filter

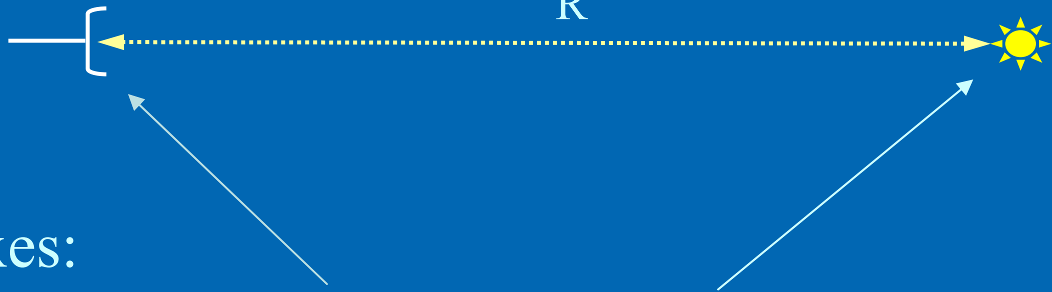
Broad band filter (UV or visible)

At the limit given by the cell geometry!

Flux vs. PMT-to-source distance

Point-light-source approximation:

If valid, no numerical simulations (unknown error bars!) are needed.



Photon fluxes:

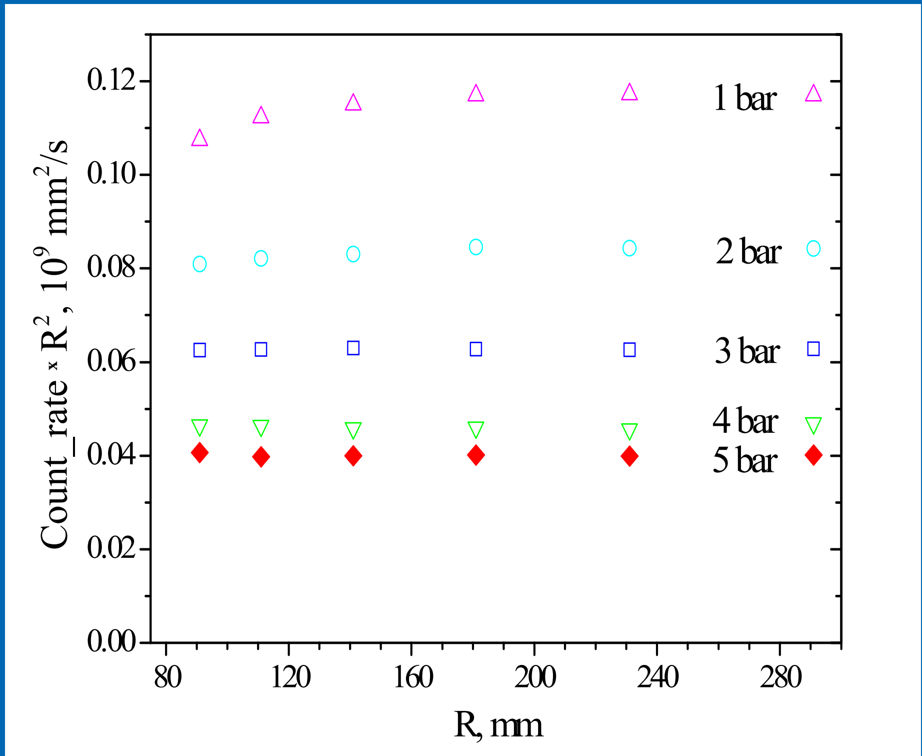
$$F_{OBSERVED} \infty N_{SOURCE} / R^2$$

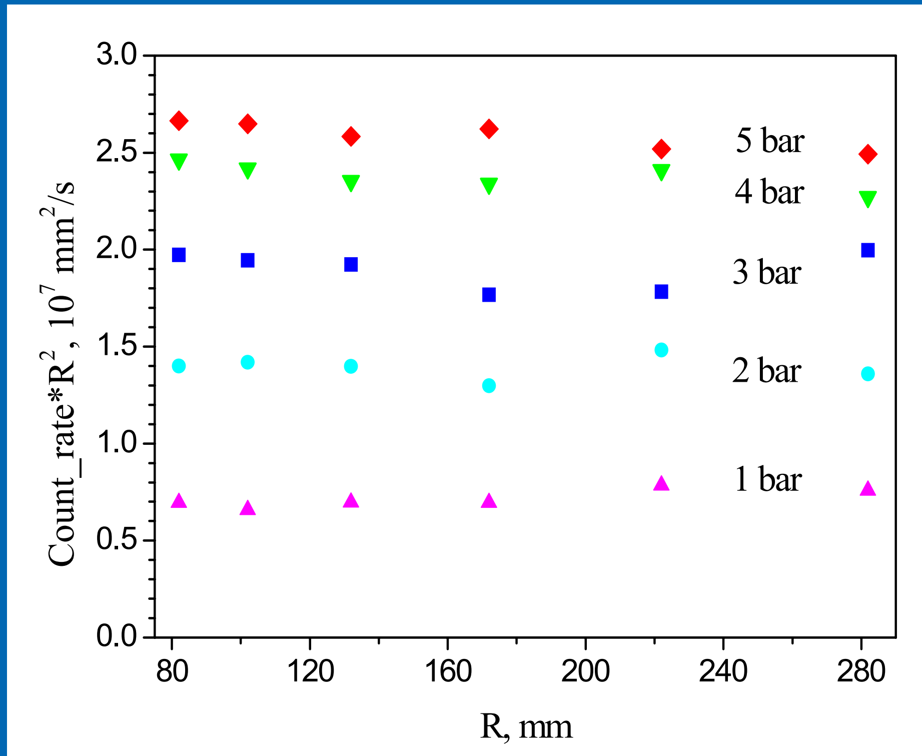
then $F_{OBSERVED} \cdot R^2$ should be constant!

Flux vs. PMT-to-source distance

UV component

VISIBLE component



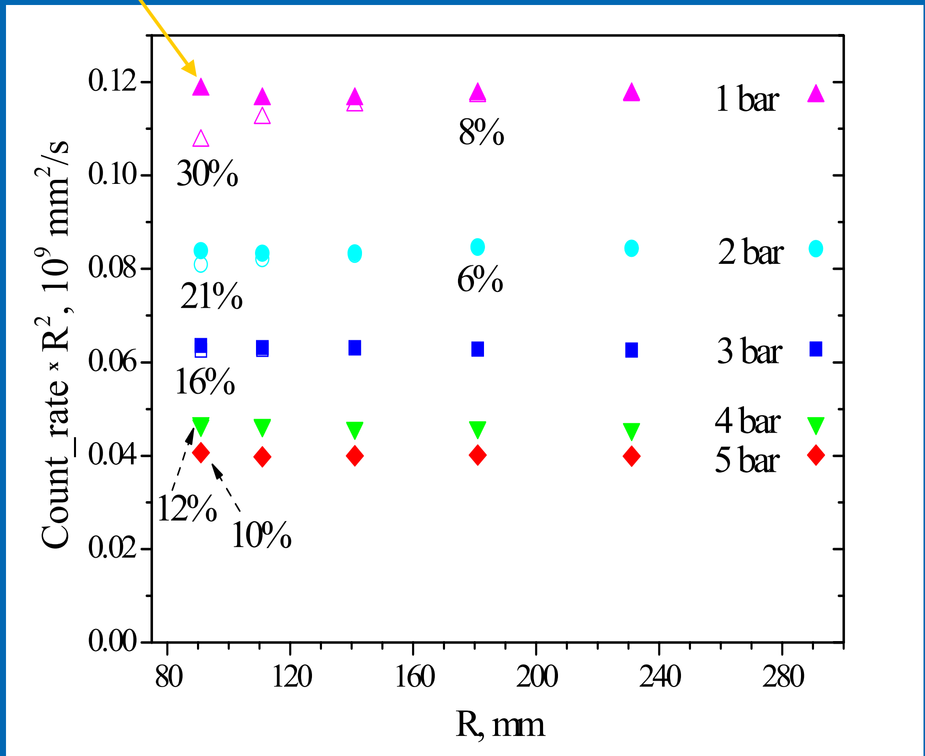


PMT can "see" the whole light emitting volume!

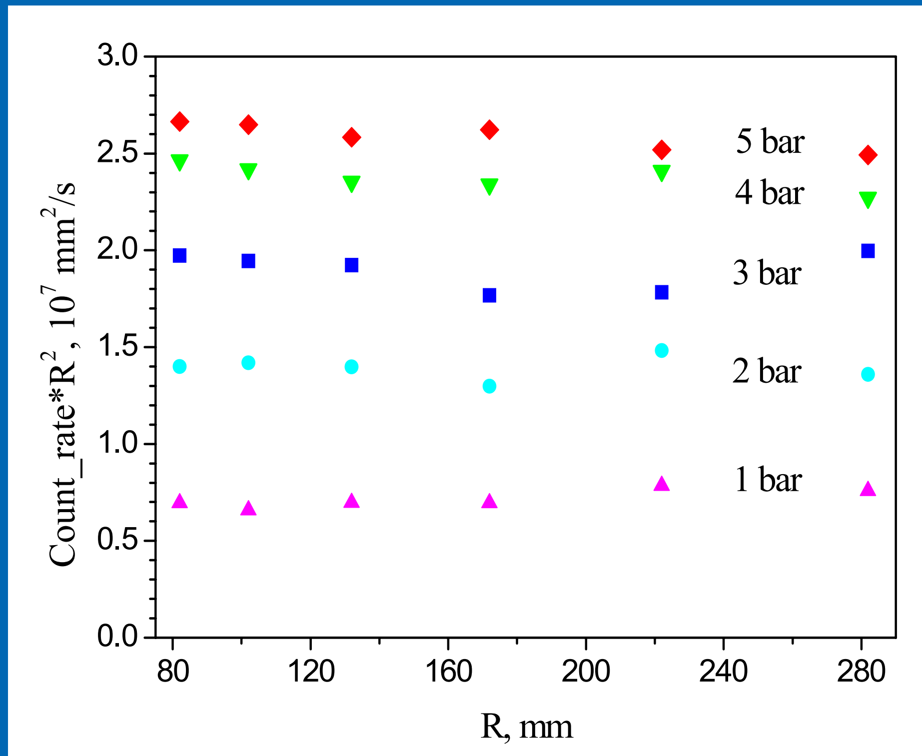
Flux vs. PMT-to-source distance

Missing double-event photoelectrons are taken into account!

UV component



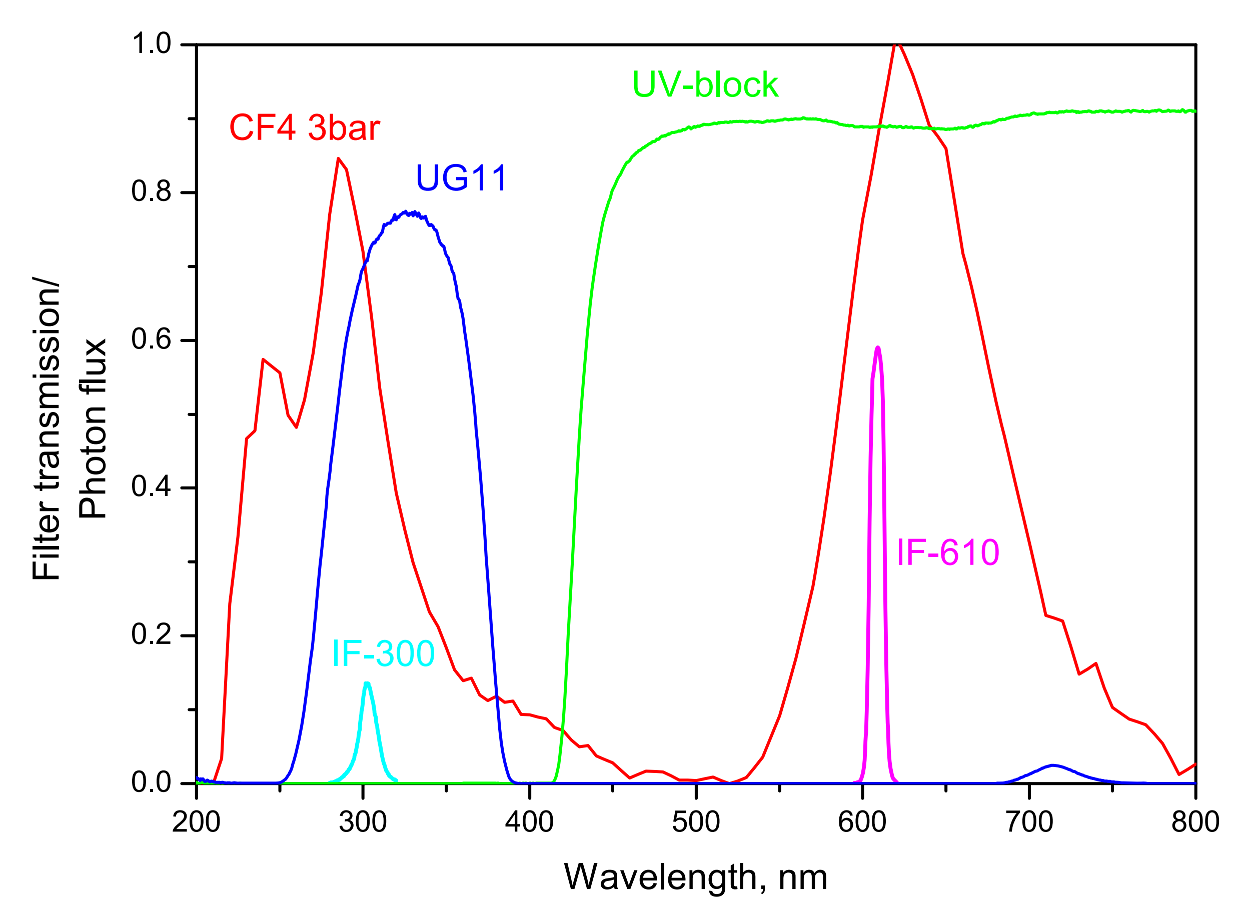
VISIBLE component



Point source approximation is definitely valid for R > 140 mm for all pressures!

No scattering!

Fluxes for the UV and VIS components



Two lines of flux measurements:

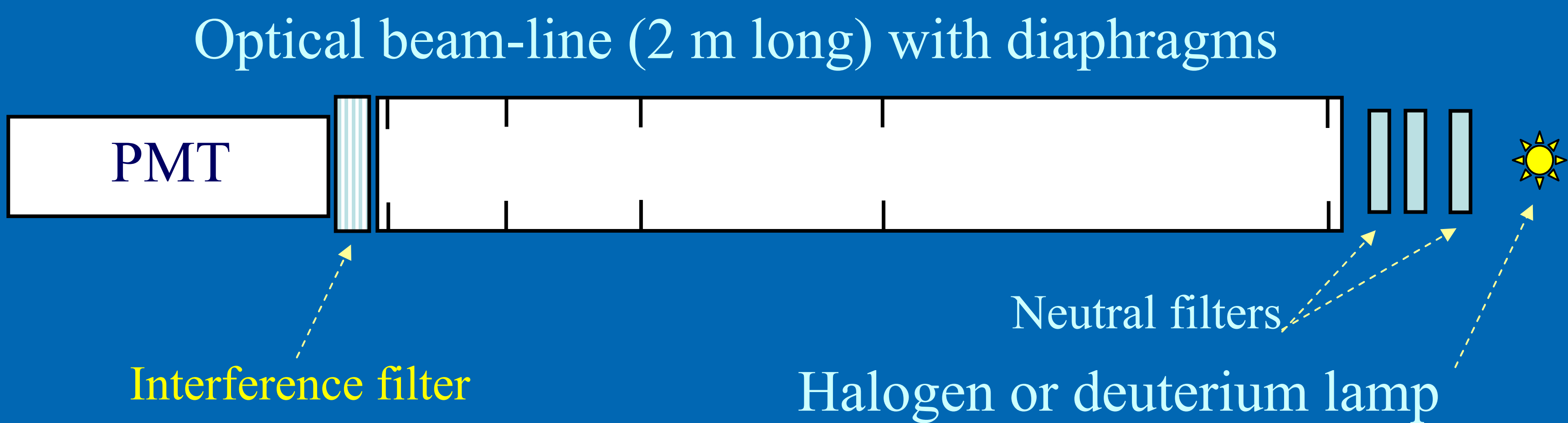
Using broad-band filters and interference filters.

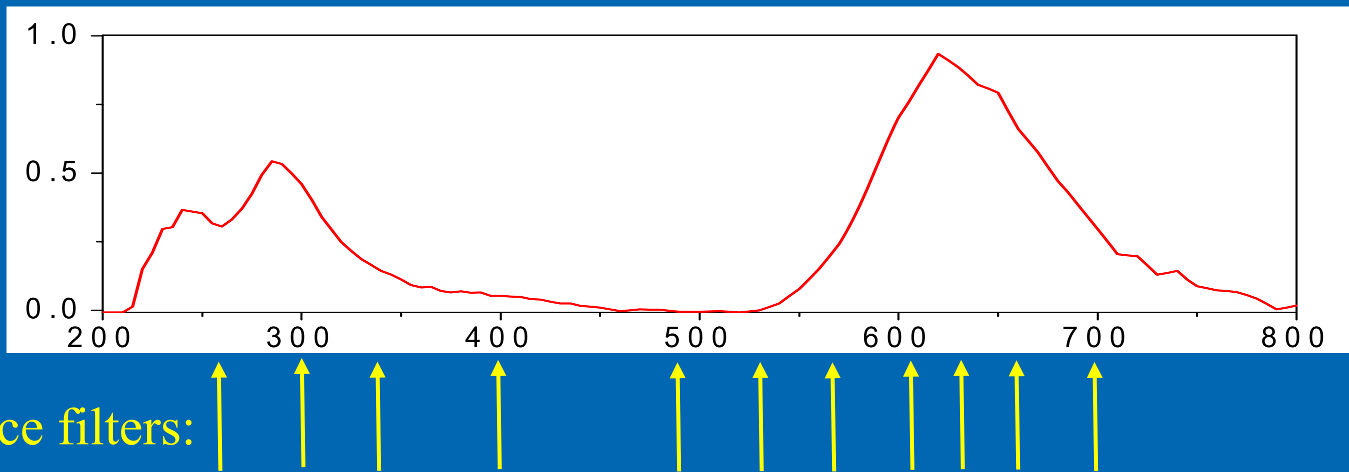
Photon detection probability vs. wavelength?

XP2020Q

R1387

Photon detection probability



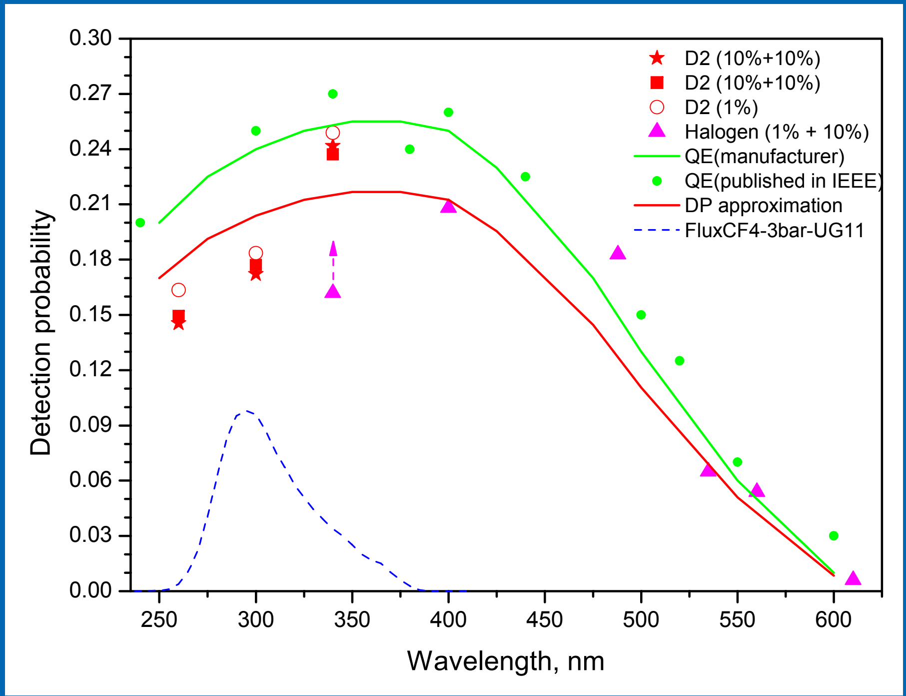


Interference filters:

Relative detection probabilities

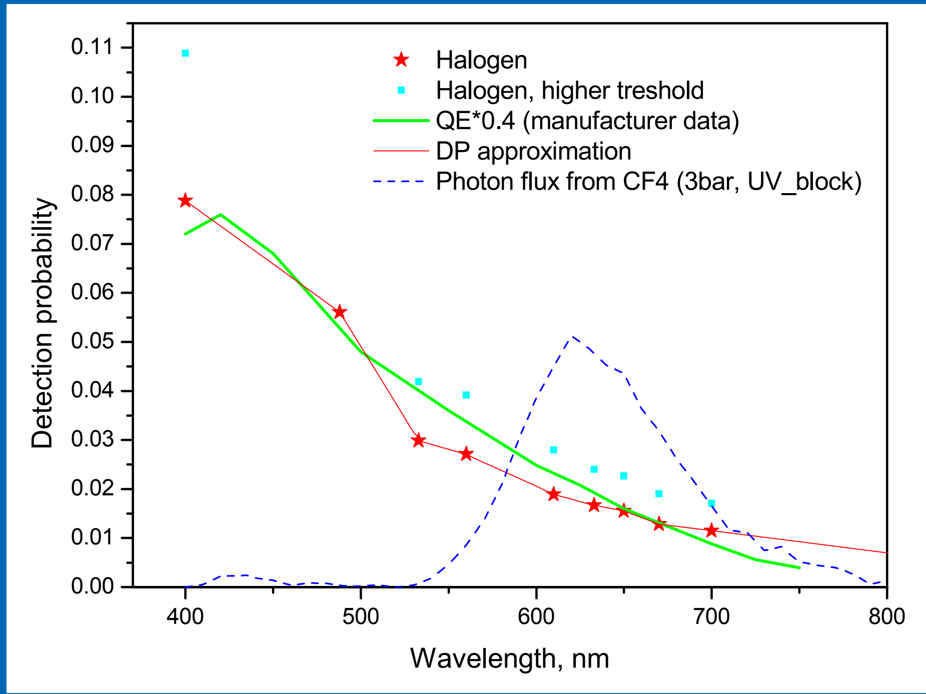
UV component

PMT: Photonis XP2020Q



Visible component

PMT: Hamamatsu R1387



Max uncertainties (main contributors: the filters and lamps):

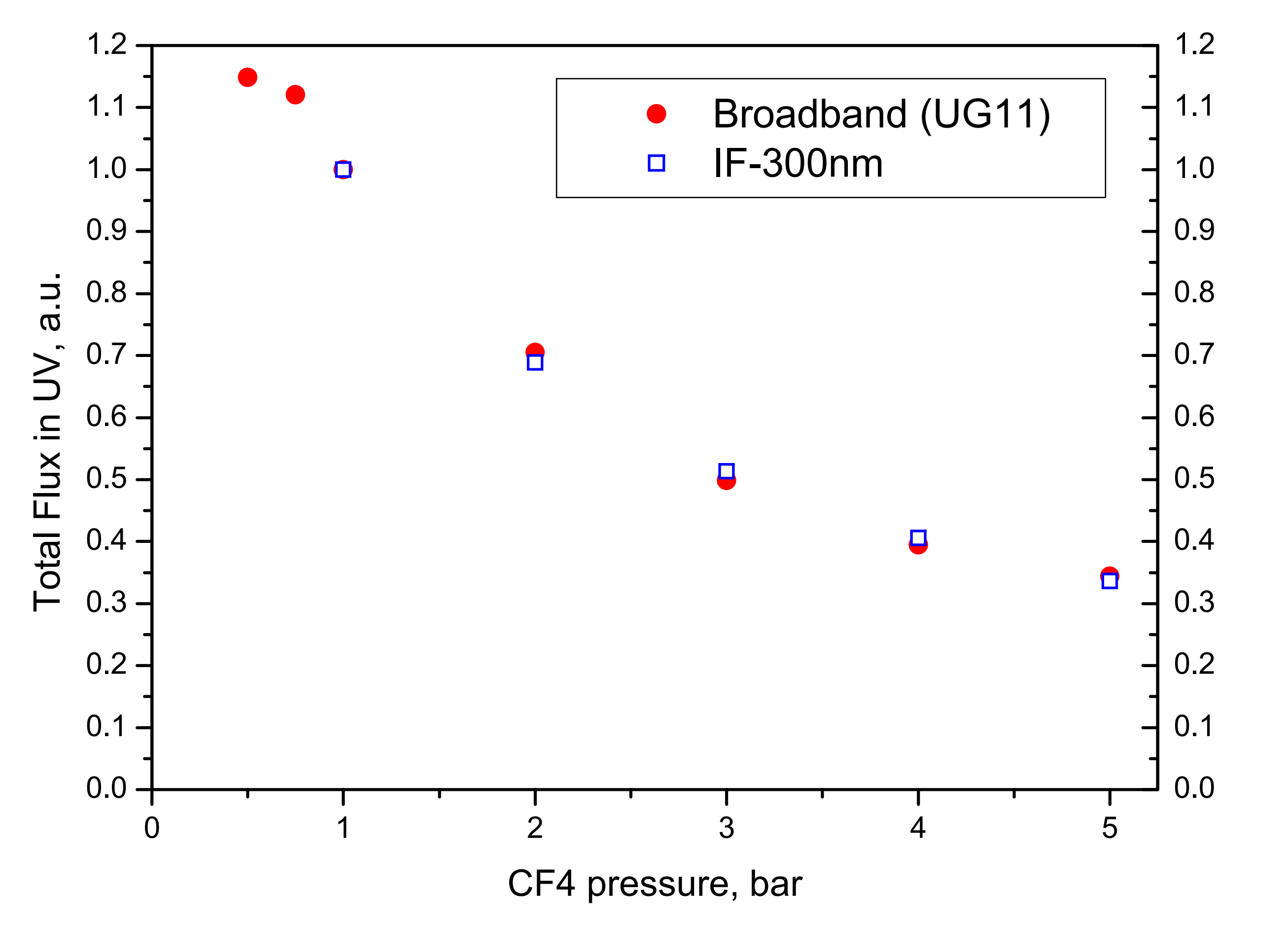
25%

35%

A. Morozov, GSPC-Meeting, December 10-11 2009

Photon flux in the UV component vs. pressure

Combining the
flux data,
effective detection
probabilities
and
filter transmission
factors
we obtain the
total flux in the UV



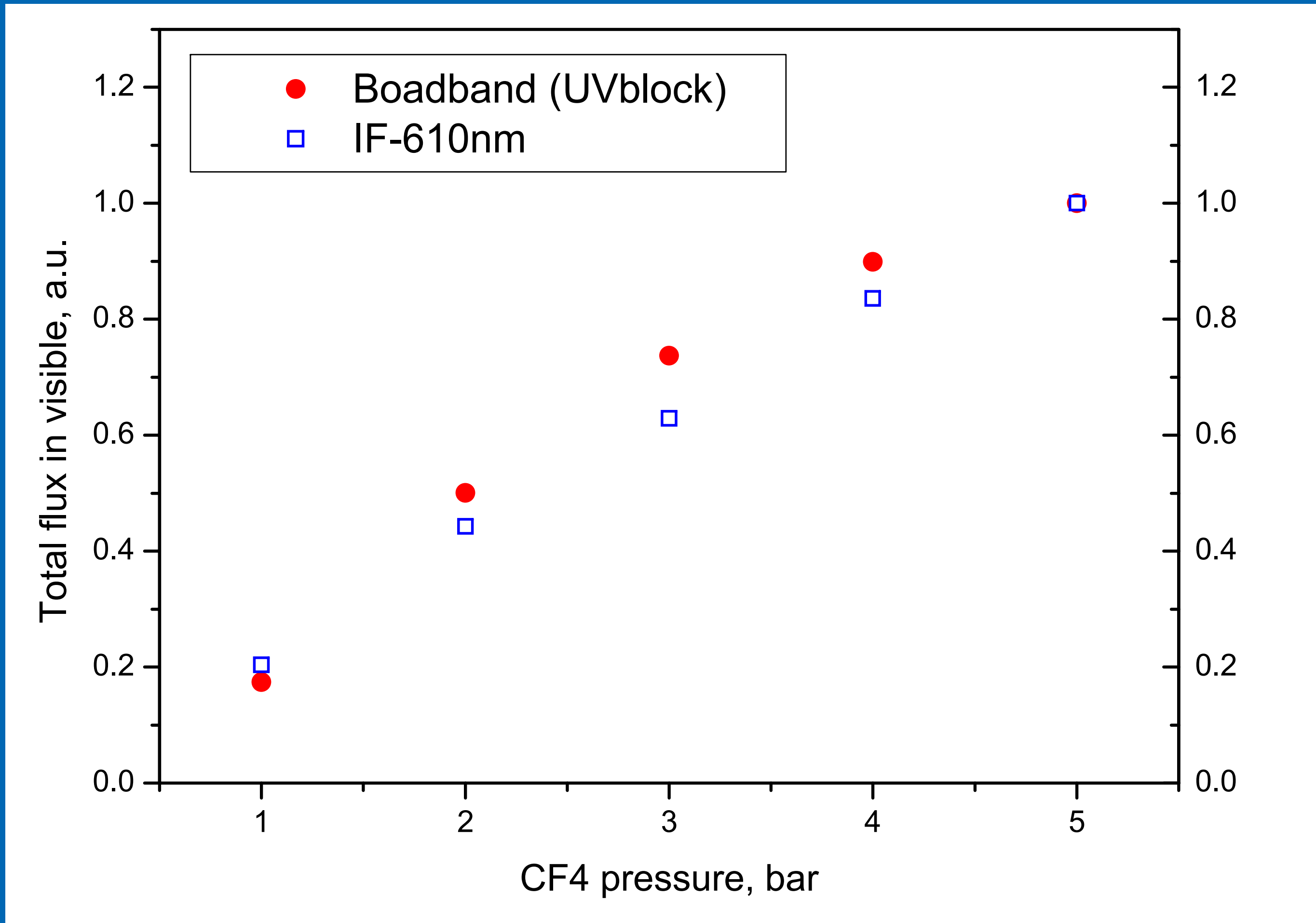
Uncertainties:

Broadband: ~5%

IF: ~10%

Photon flux in the visible component vs. pressure

Similarly, the total flux in the visible component



Uncertainties:

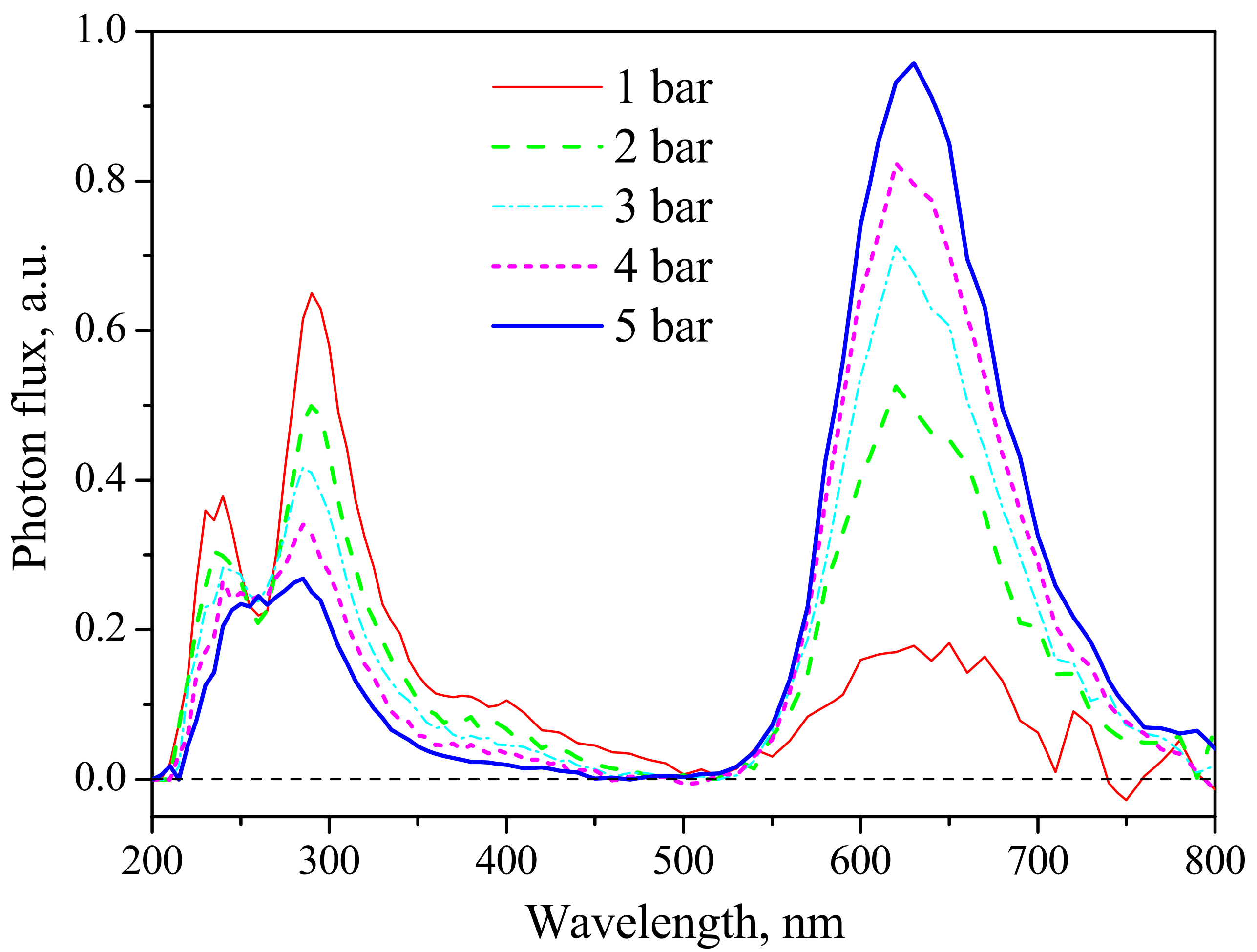
Broadband: ~10%

IF: 20%@5bar

70%@1bar

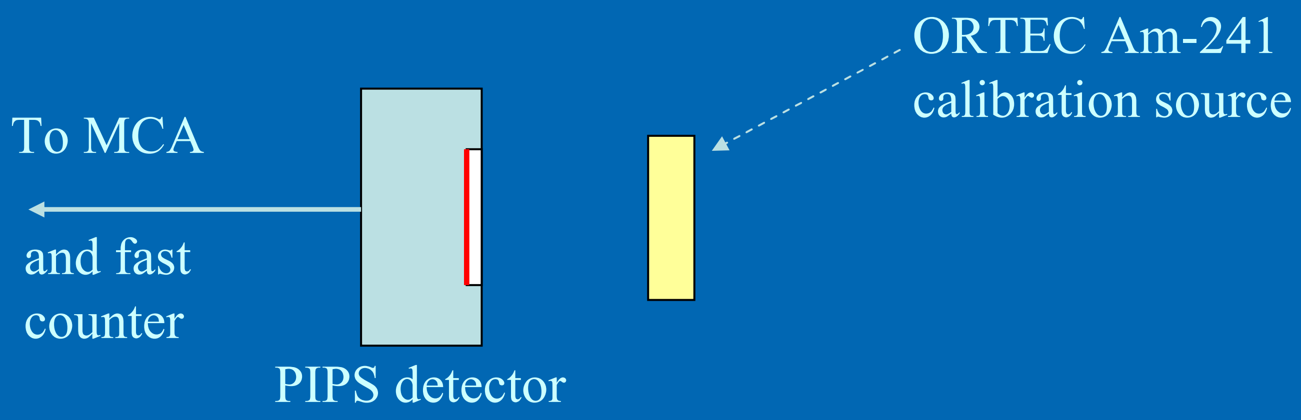
CF_4 emission spectra (all corrections are applied)

Flux measurements have been used to scale the spectra from different pressures

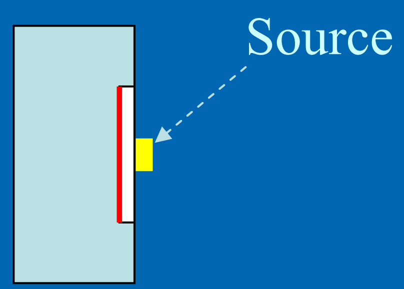


α-source characterization

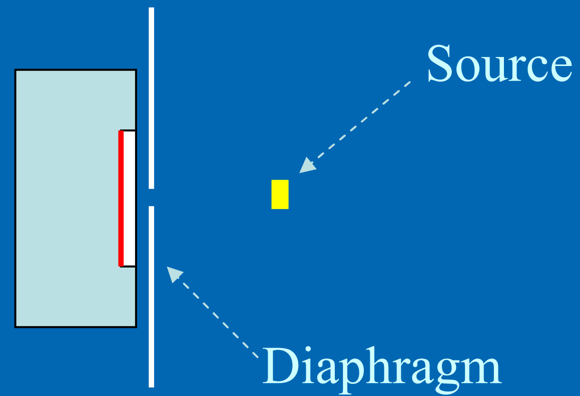
α-source characterization



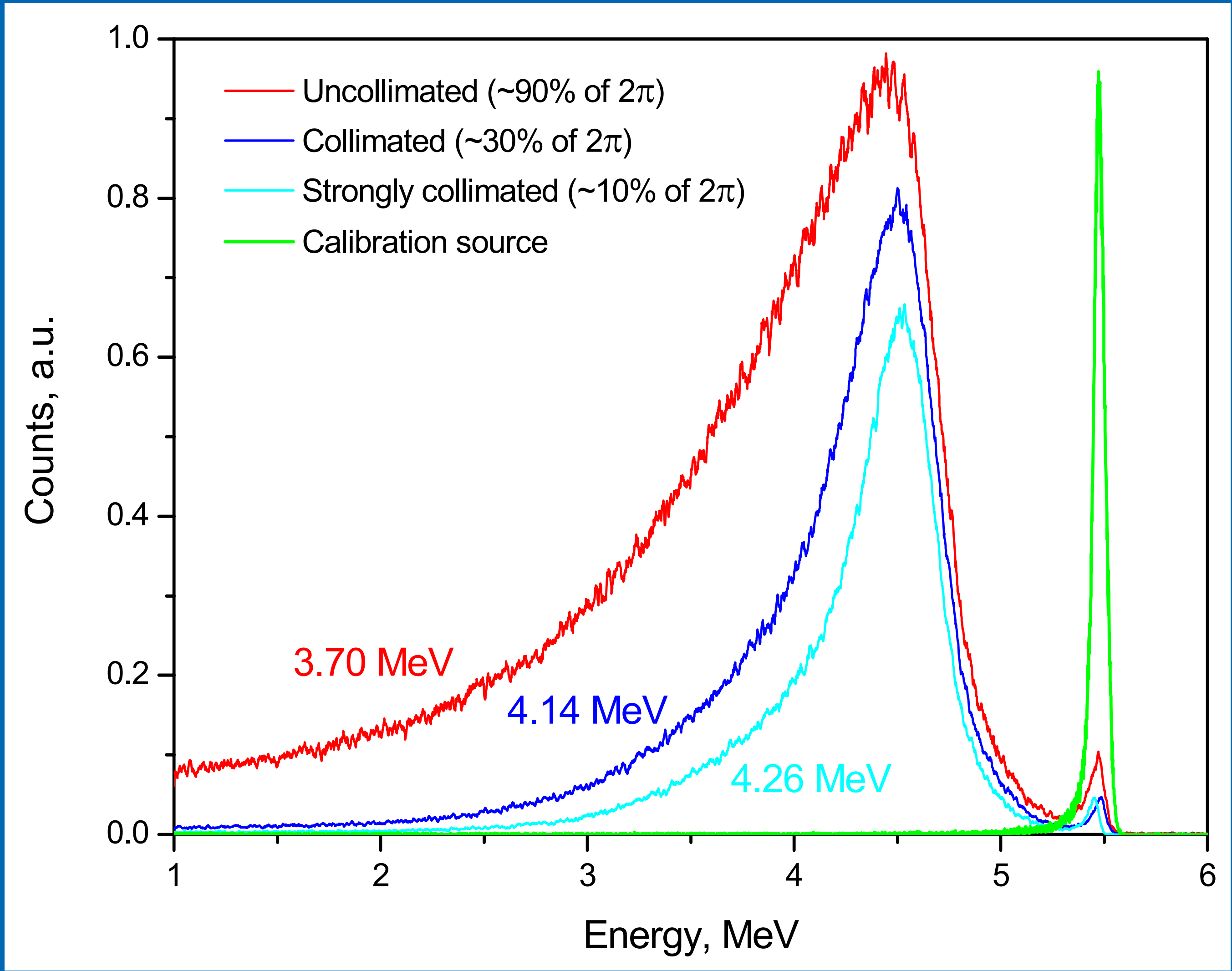
~2π emission



Collimated emission



α-source characterization



Average energy of α-particles:

3.70 ± 0.05 MeV

α flux in 2π:

$42100 \pm 100\ s^{-1}$

Photon yield

Photon yield calculation

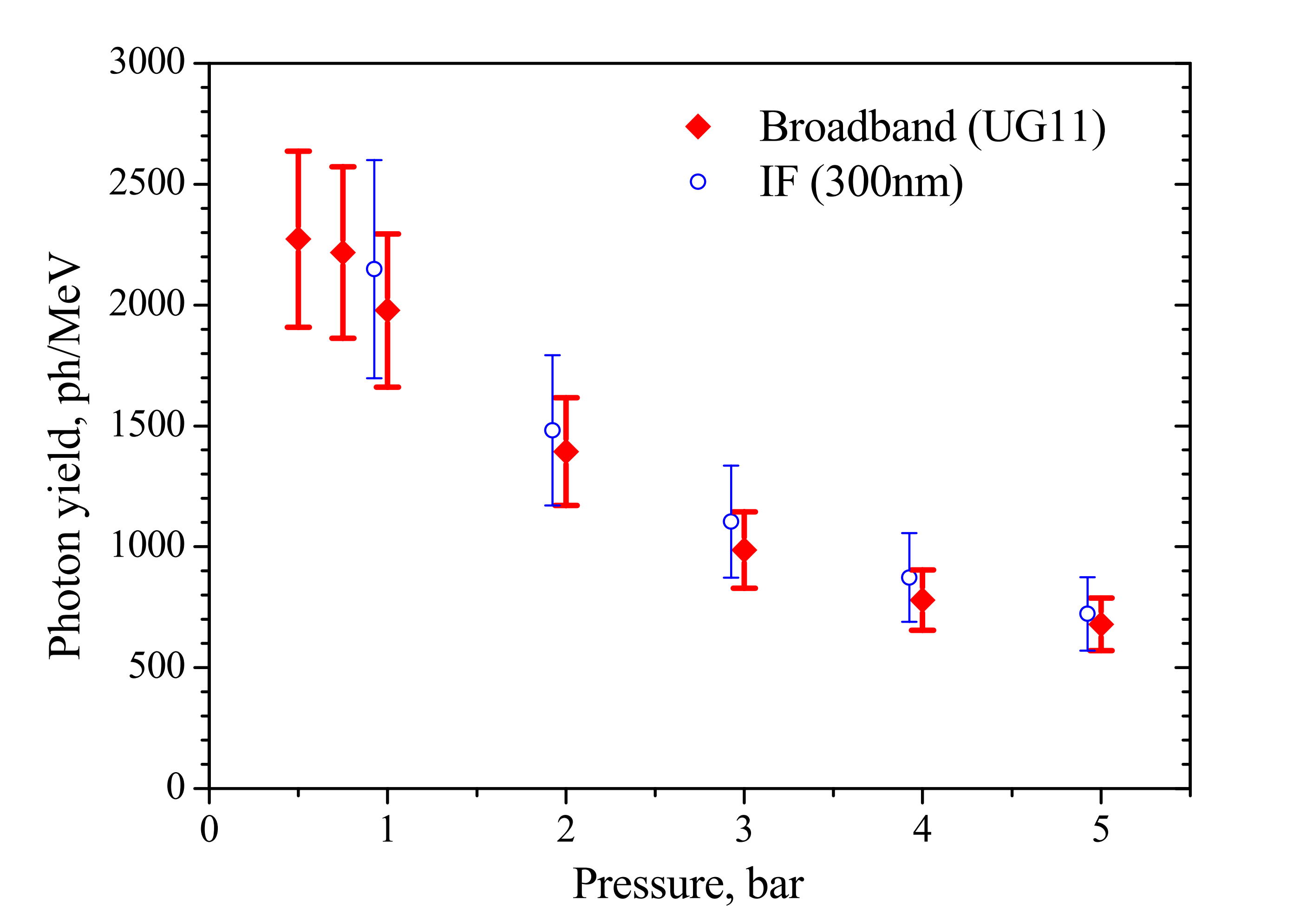
Photon yield: Number of photons (in 4π) produced per MeV of energy deposited in the gas.

$$Y = \text{Number\_of\_photons} / (\alpha\text{-Rate} \cdot \text{Average\_Energy})$$

From photon flux measurements

Number of α-particles entering the gas per second multiplied by the average deposited energy

Photon yield (UV component, integrated)



Uncertainties

Broadband:

16% sum in quadrature

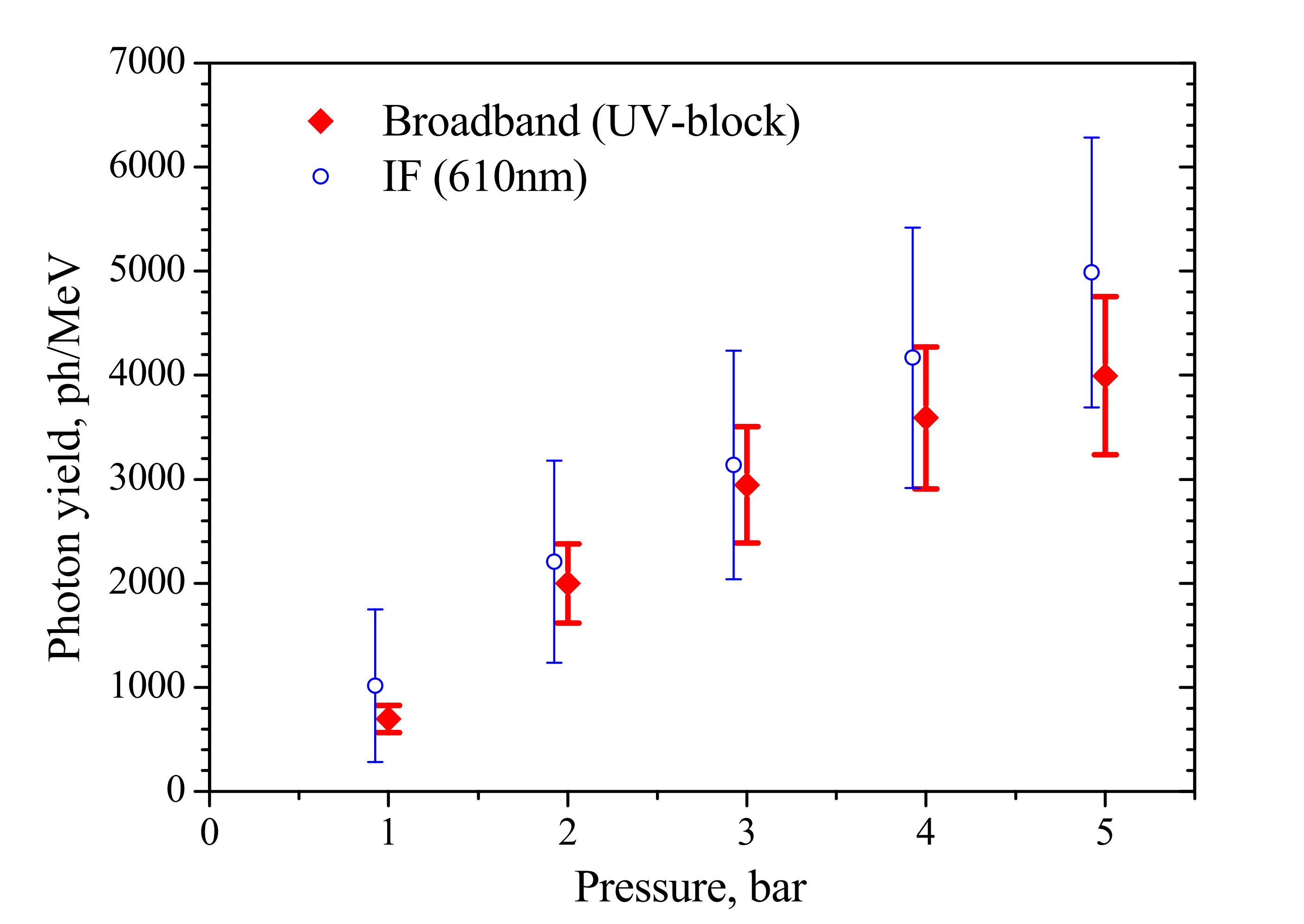
(40% sum)

IF-300 nm:

21% sum in quadrature

(55% sum)

Photon yield (visible component, integrated)



Uncertainties

Broadband:

19% sum in quadrature

(50% sum)

IF-300 nm:

5 → 1bar:

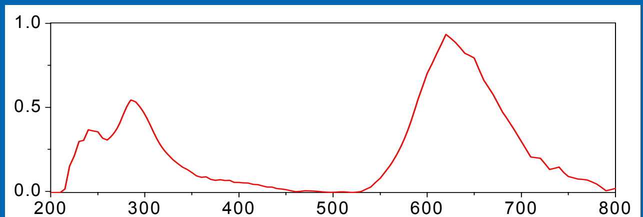
26% → 72% sum in quadrature

(67% → 120% sum)

Photon yield: cross-check

The ratios of yields in the UV and visible are compared with the flux ratios from the calibrated emission spectra

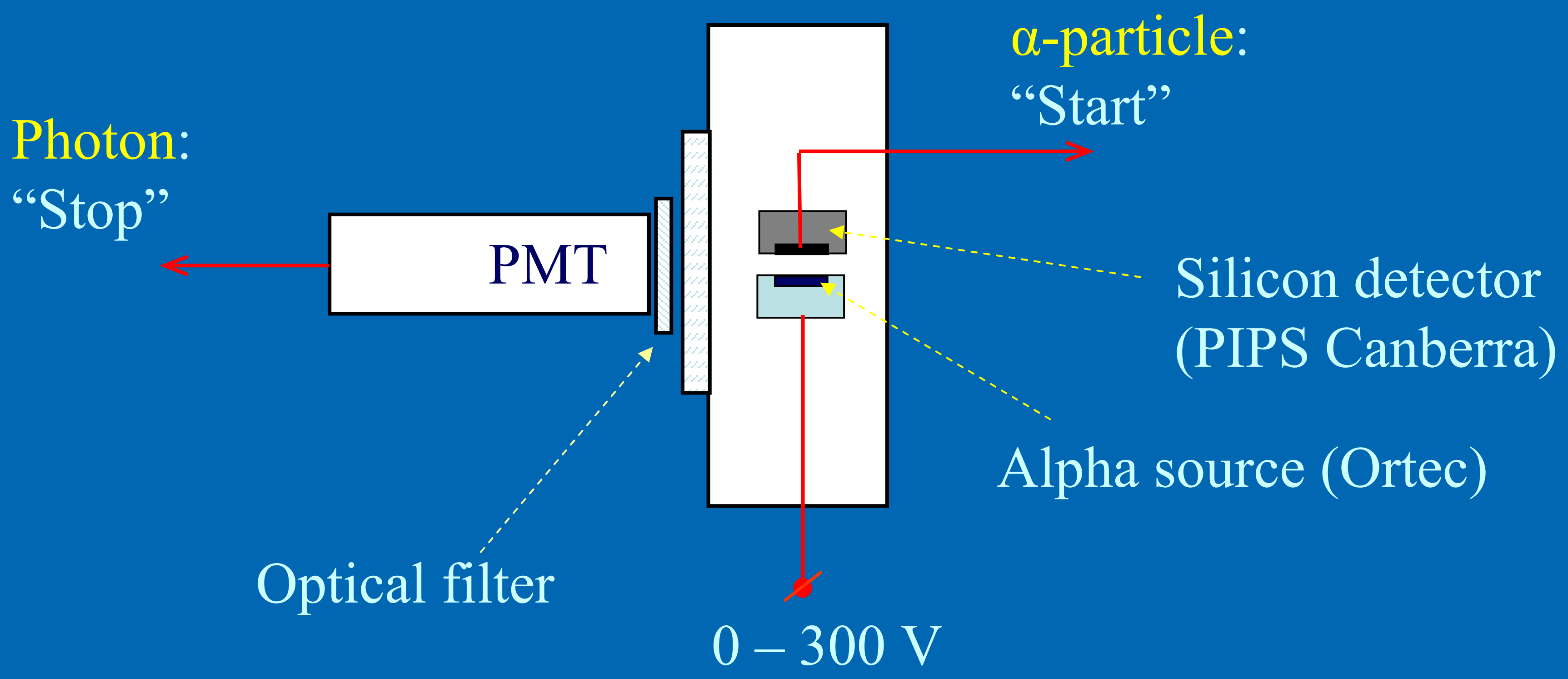
P bar	Yield ratios UV / vis	Spectral ratios UV / vis
1	2.8 ± 1.0	~2.5 ± 0.8
2	0.70 ± 0.25	0.76 ± 0.15
3	0.34 ± 0.12	0.50 ± 0.10
4	0.22 ± 0.08	0.35 ± 0.07
5	0.17 ± 0.06	0.23 ± 0.05



Overlap!

Time spectra

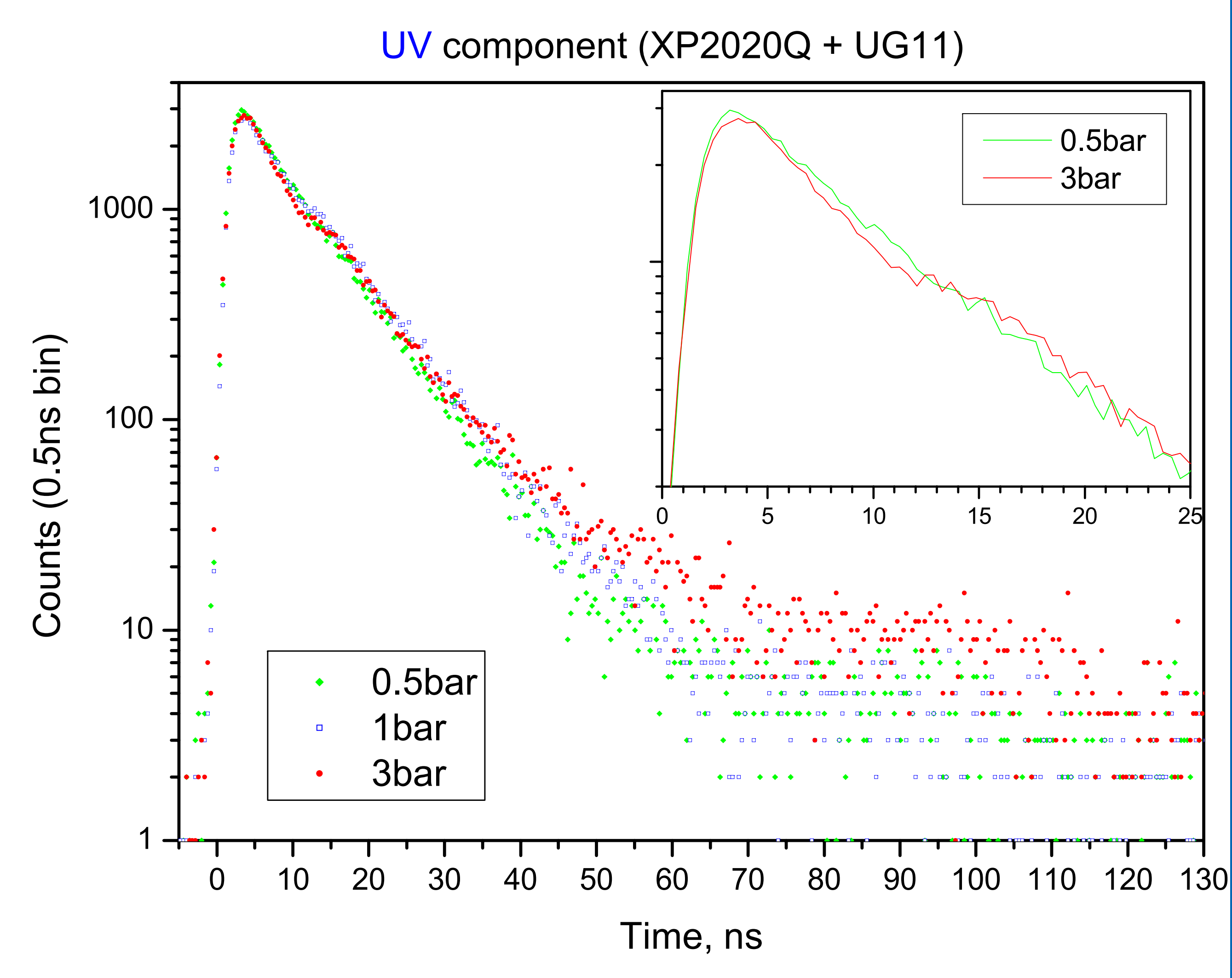
Time spectra: setup



Electronics:

Start and stop → fast preamps → CF triggers → Time-to-amplitude converter → Multi-channel analyzer

Time spectra: UV component

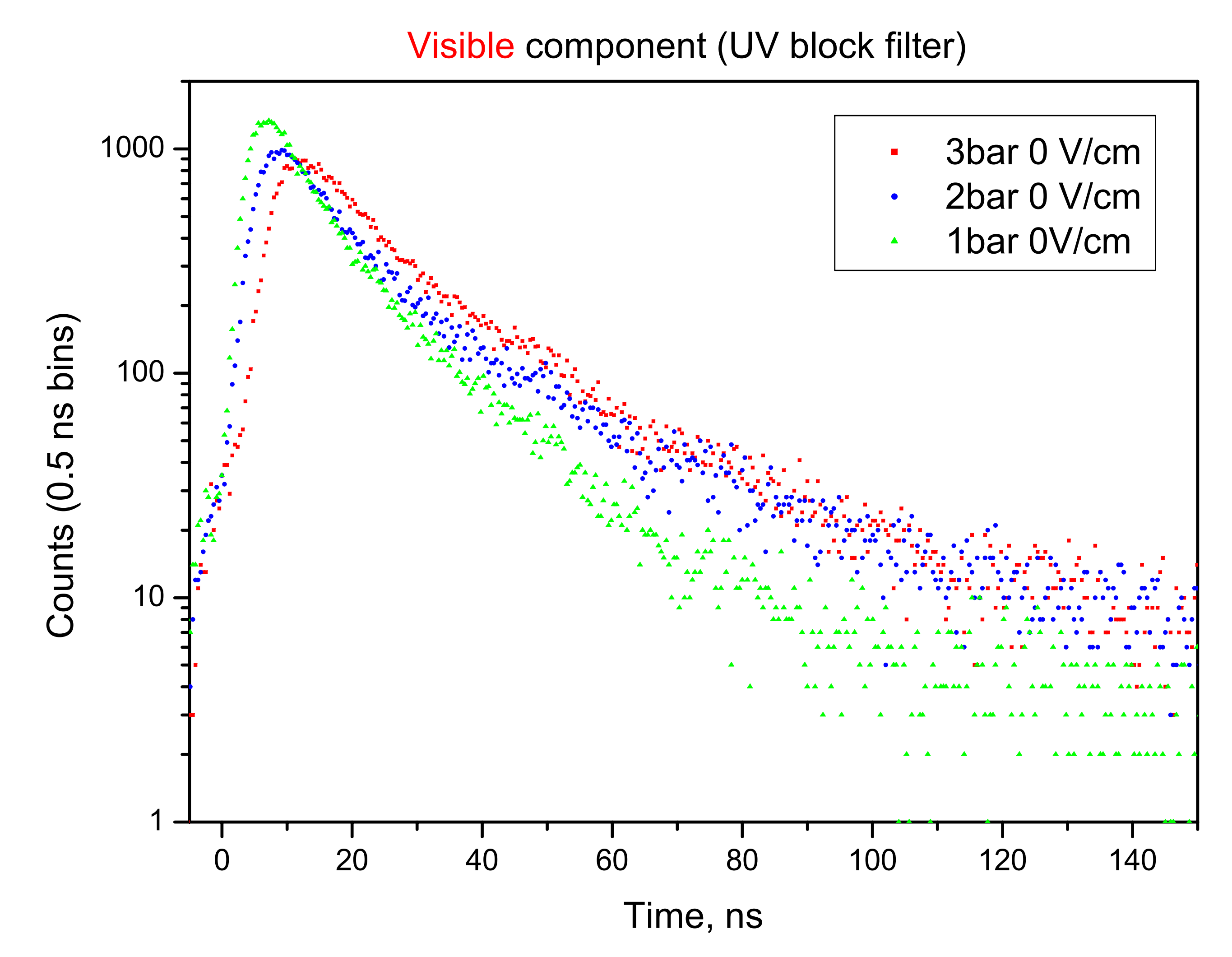


Two distinctive decay structures (both ? exponential)

Indications of a very weak non-exponential tail

Weak pressure dependence

Time spectra: Visible component



Strongly non-exponential decay

Very likely there is a strong contribution from recombination

Clear pressure dependence

Typical effective lifetimes

Effective lifetimes measured in the absence of electric field are:

~4 – 6 ns   for the UV component

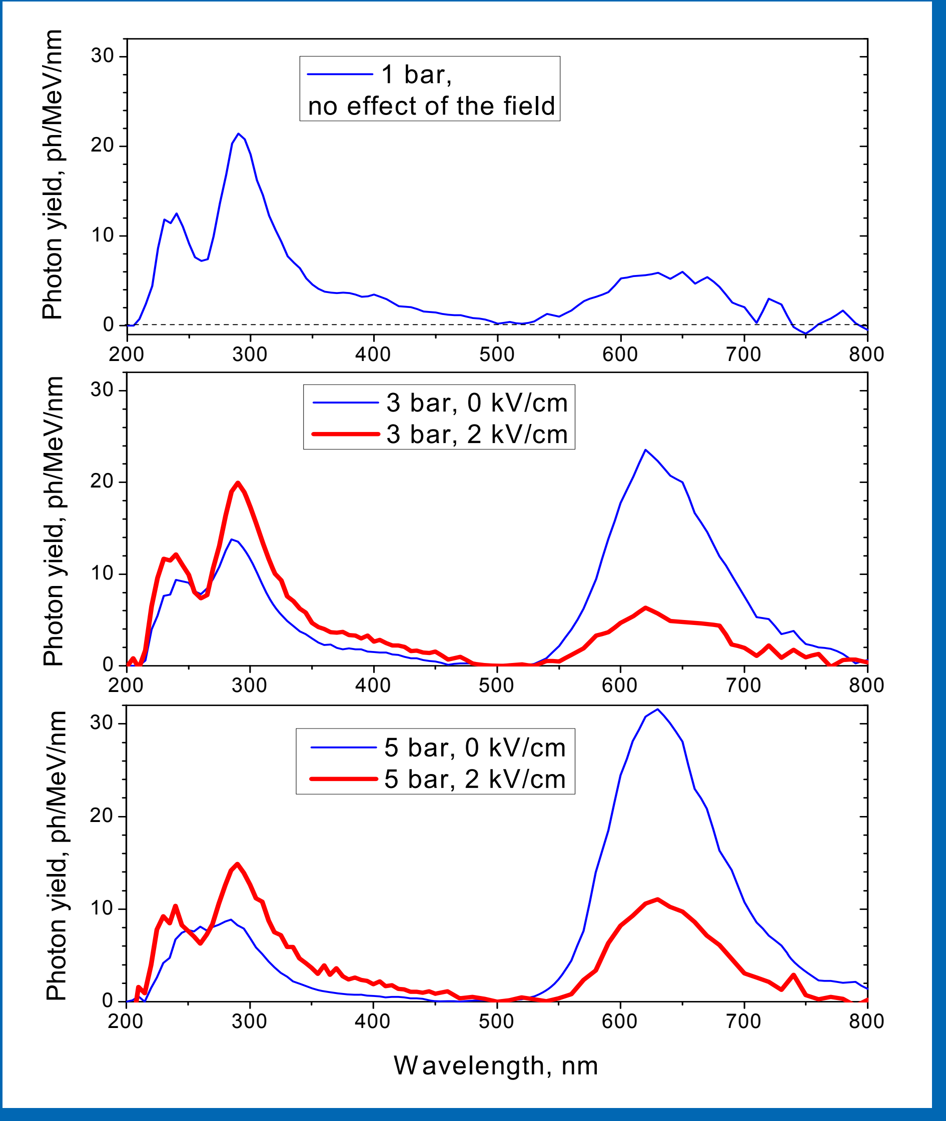
and

~8 – 16 ns   for the visible component

Both the visible and UV time spectra show no indications of any slow (effective lifetime on the order of 100ns and longer) decay components.

Effect of the electric field

Electric field: Spectra

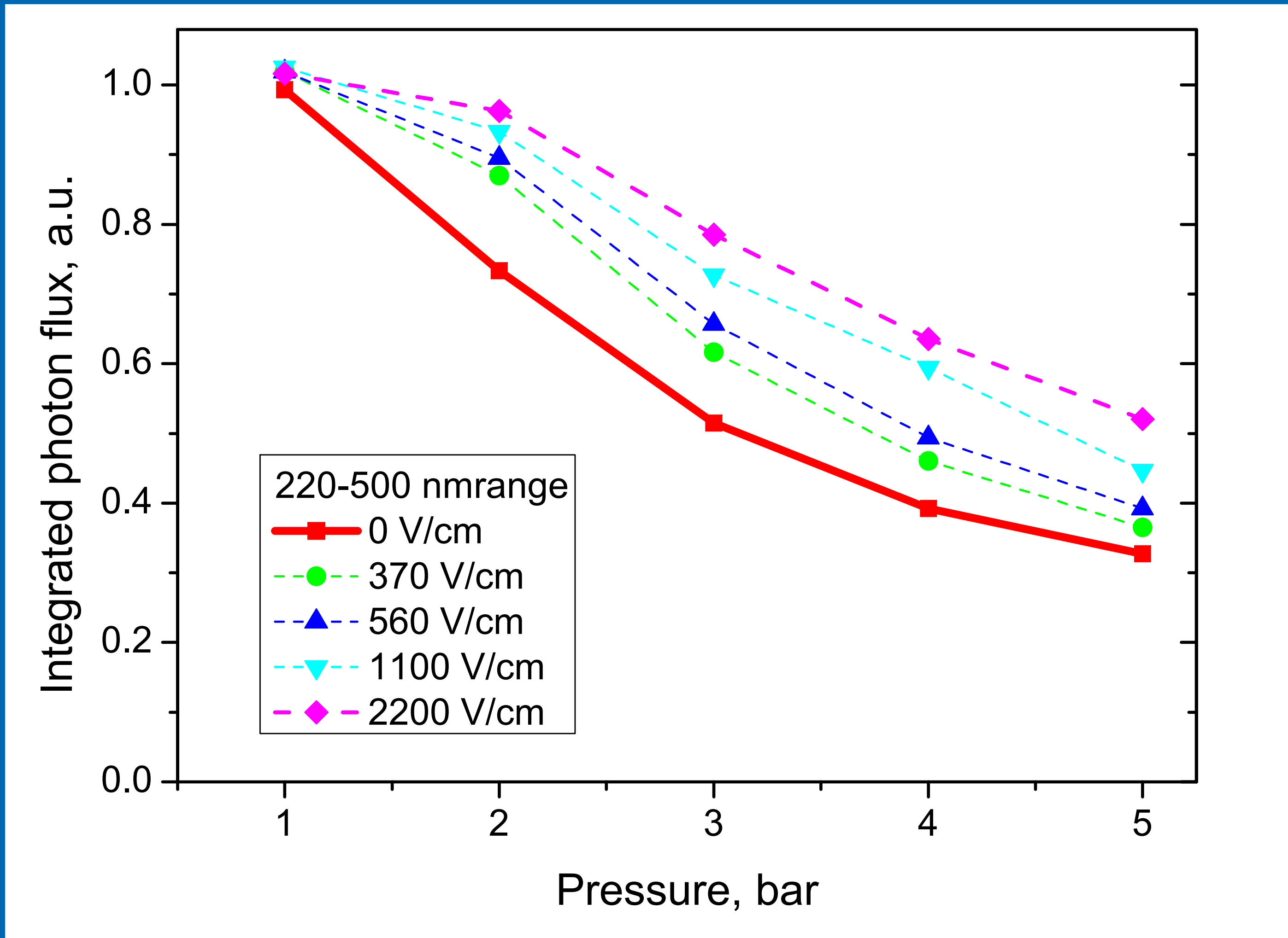


No effect for low pressures!

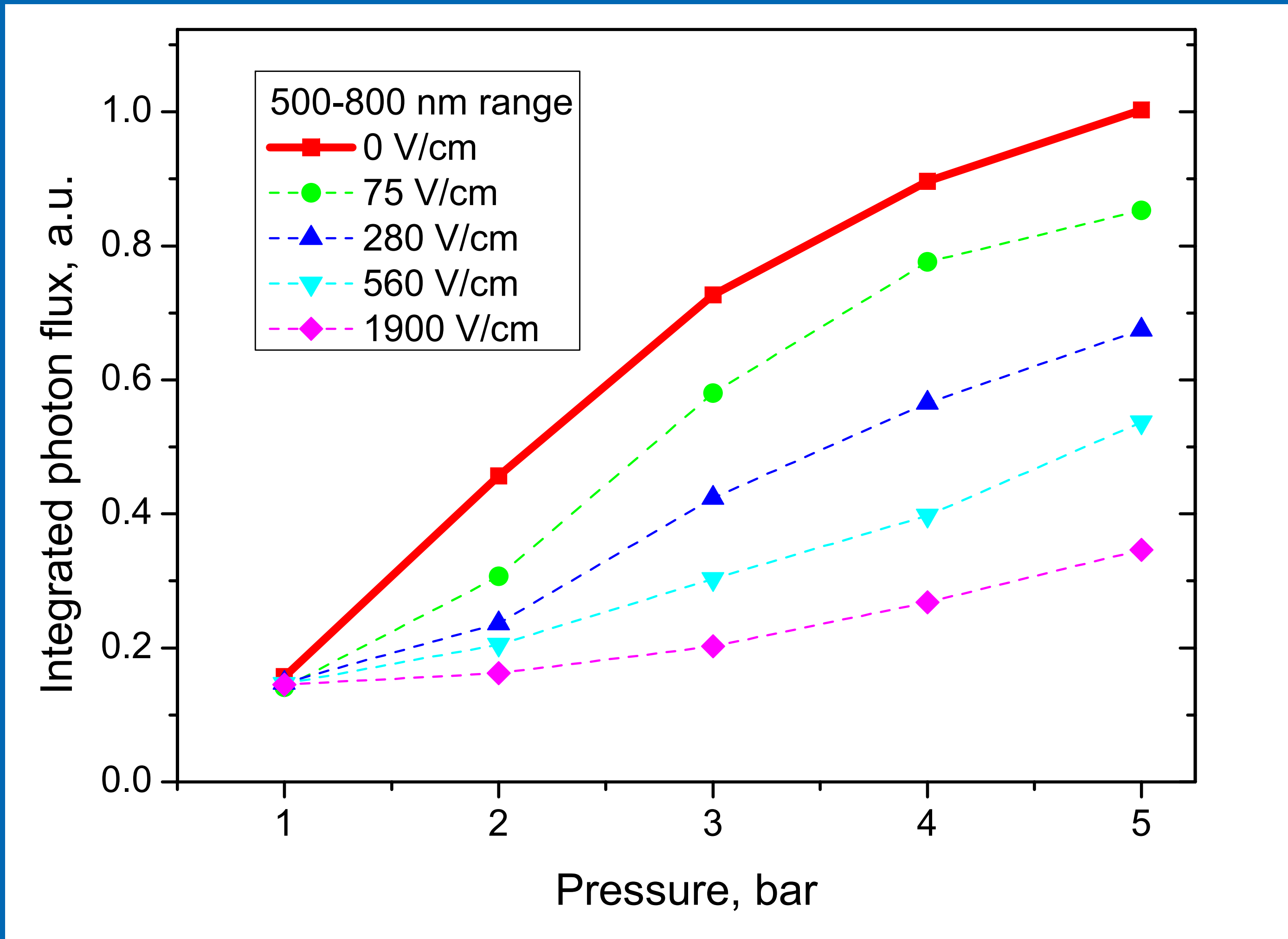
For medium-high pressures:
Very strong reduction of the visible component and an increase of the UV component with the field!

At 5 bar:
Strong reshaping of the UV component with the field!

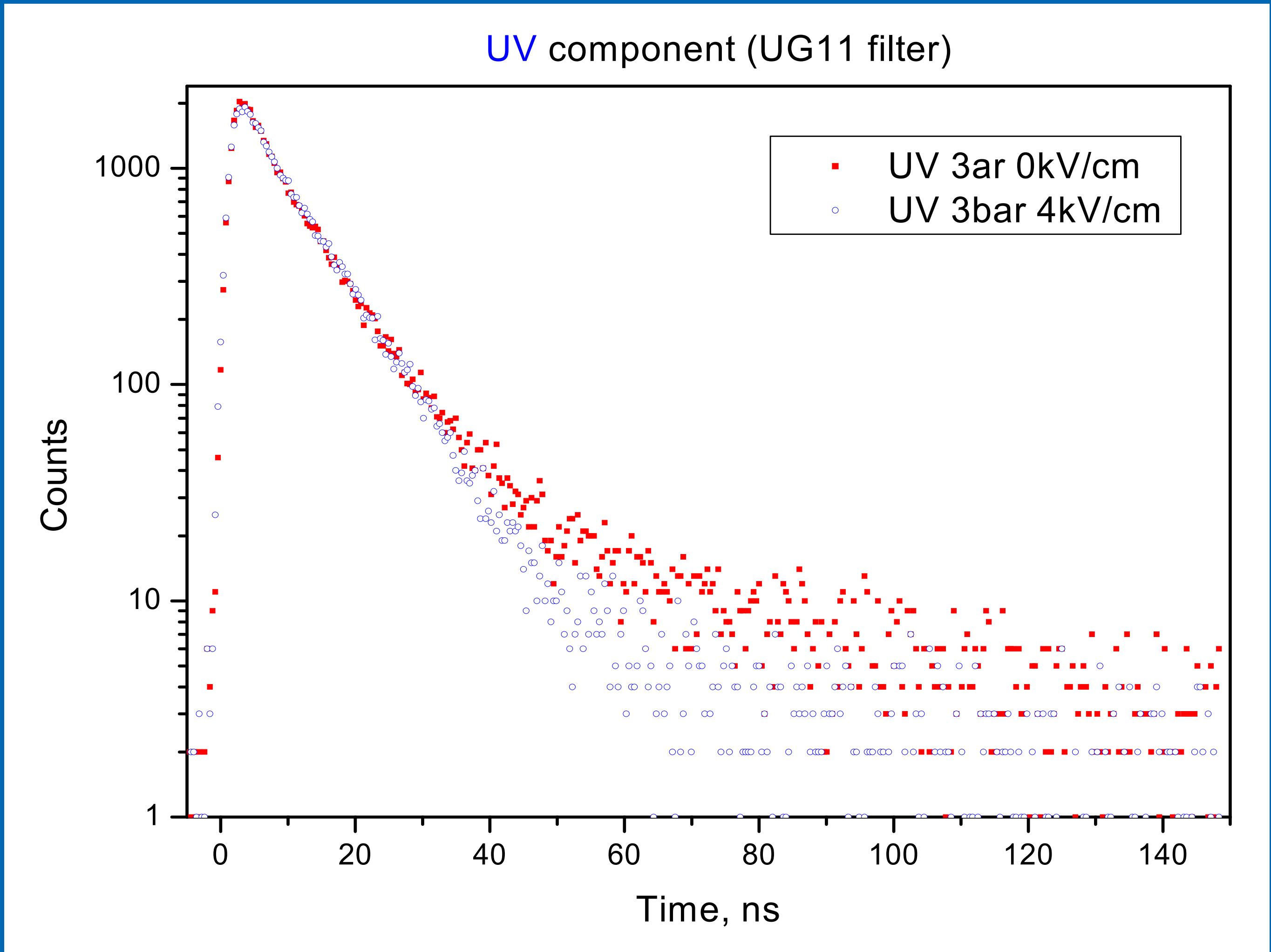
Electric field: UV component



Electric field: Visible component

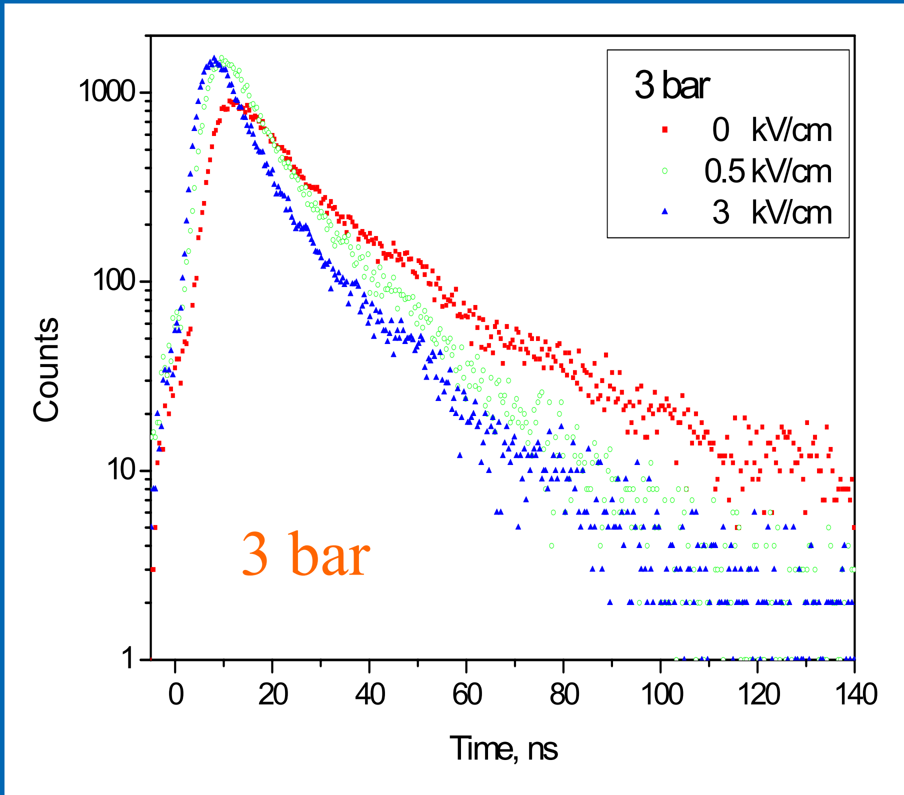


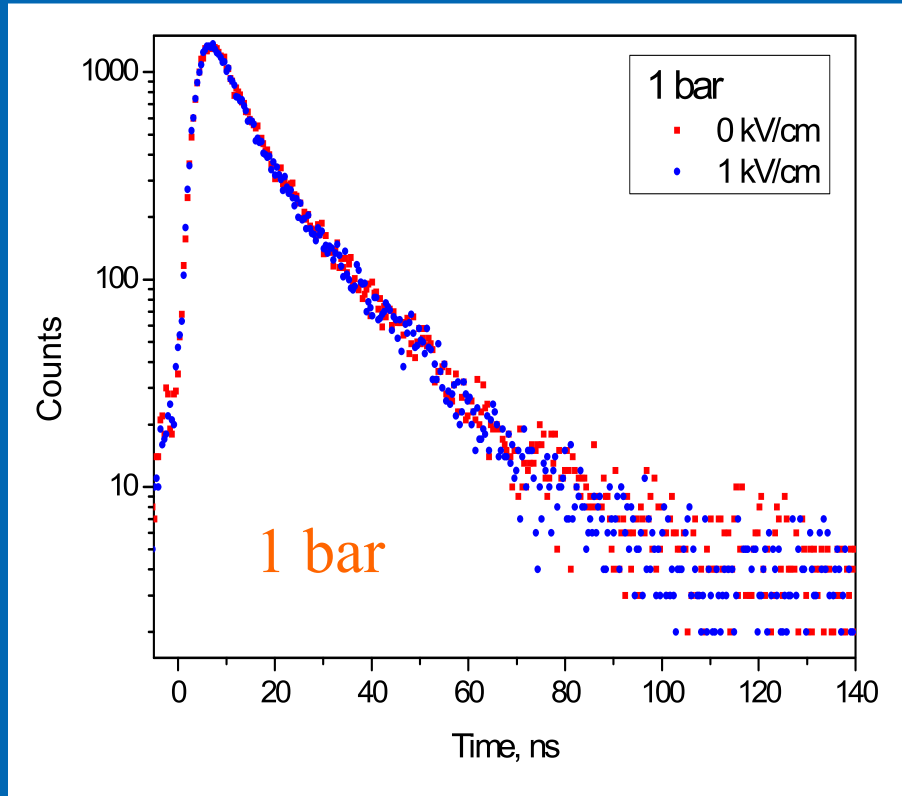
Electric field:
Time spectra of the UV component



Very small difference!

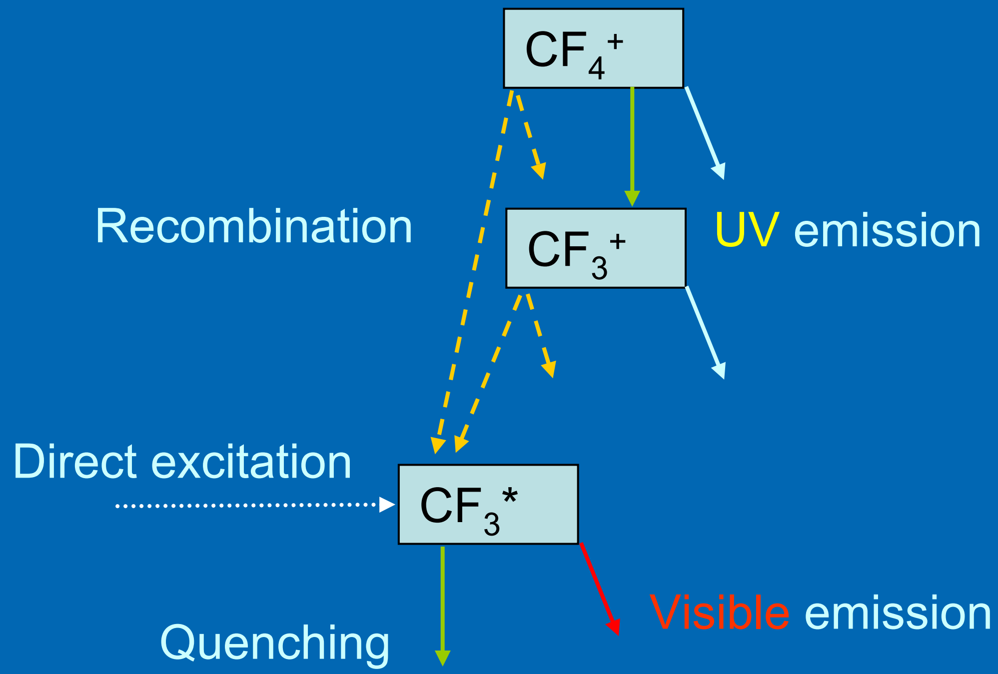
E-field dependence: Visible component





Very different behavior at high and low pressures!

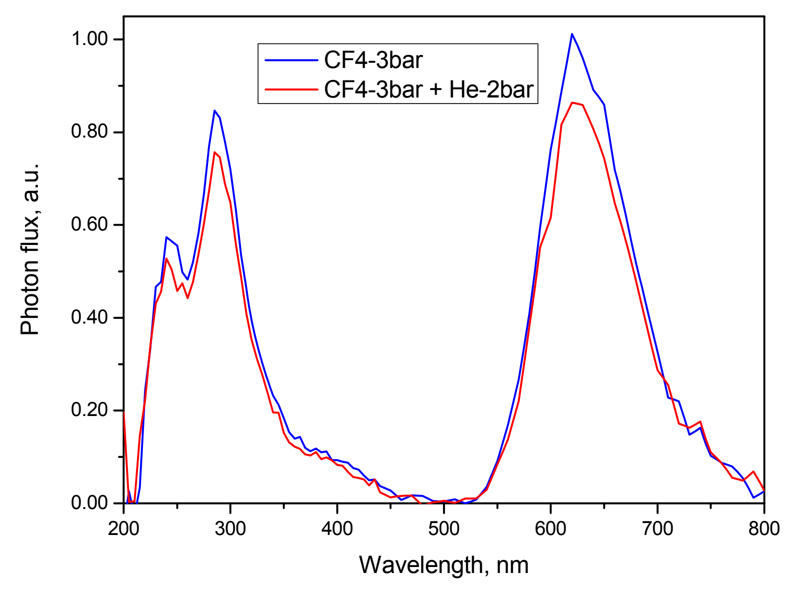
E-field dependence: Why UV and visible behave differently?

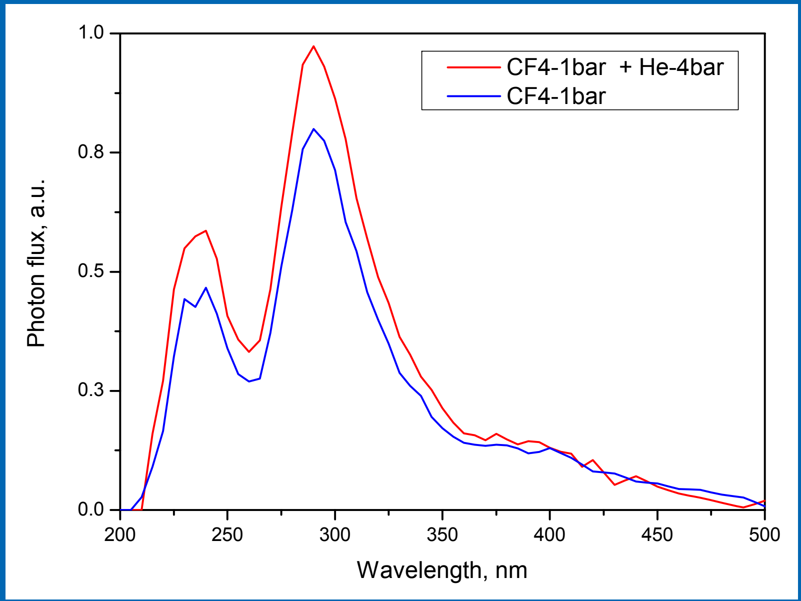


Electric field suppresses recombination

UV emission benefit from that while visible emission should be reduced

Effect of helium: spectra and flux measurements





Absolute flux measurements:

UV component
(pressures are in bar)

3 CF_4 + 2 He: same as 3 CF_4

2 CF_4 + 3 He: 20% higher than 2 CF_4

1 CF_4 + 4 He: 40% higher than 1 CF_4

Visible component
(pressures are in bar)

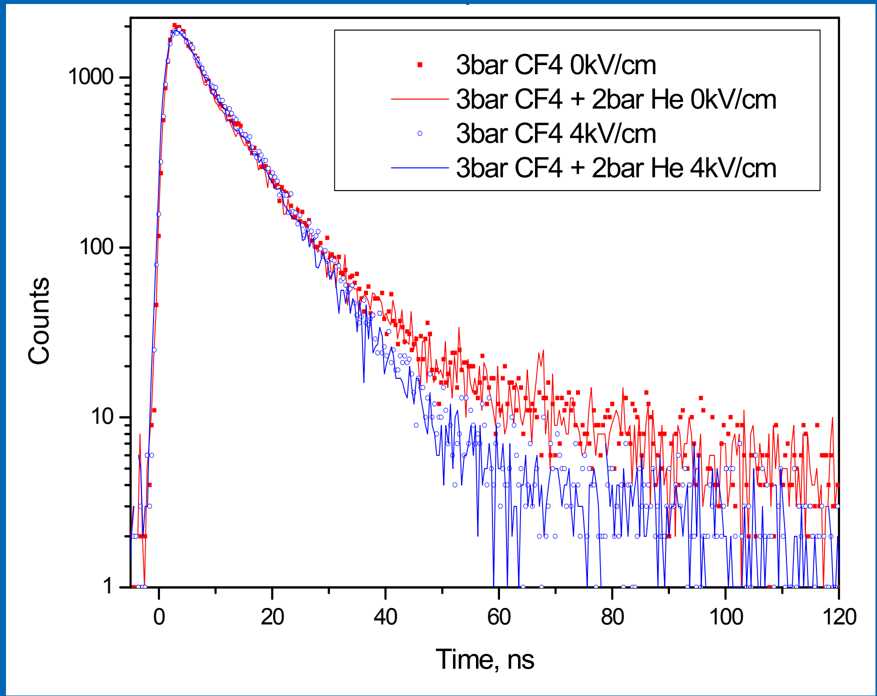
3 CF_4 + 2 He: same as 3 CF_4

2 CF_4 + 3 He: same as 2 CF_4

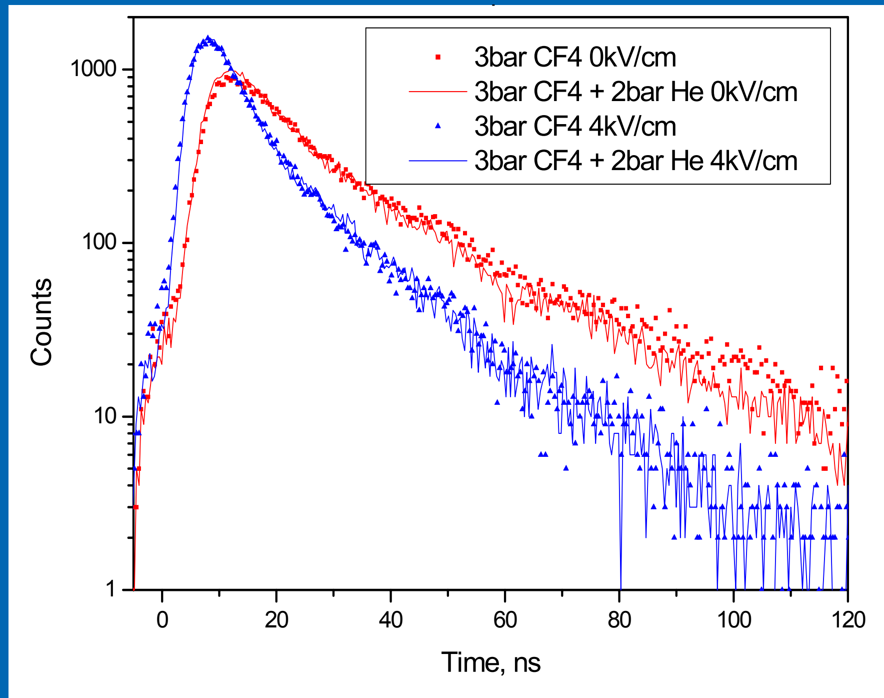
1 CF_4 + 4 He: same as 1 CF_4

Effect of helium: Time spectra

UV component



Visible component

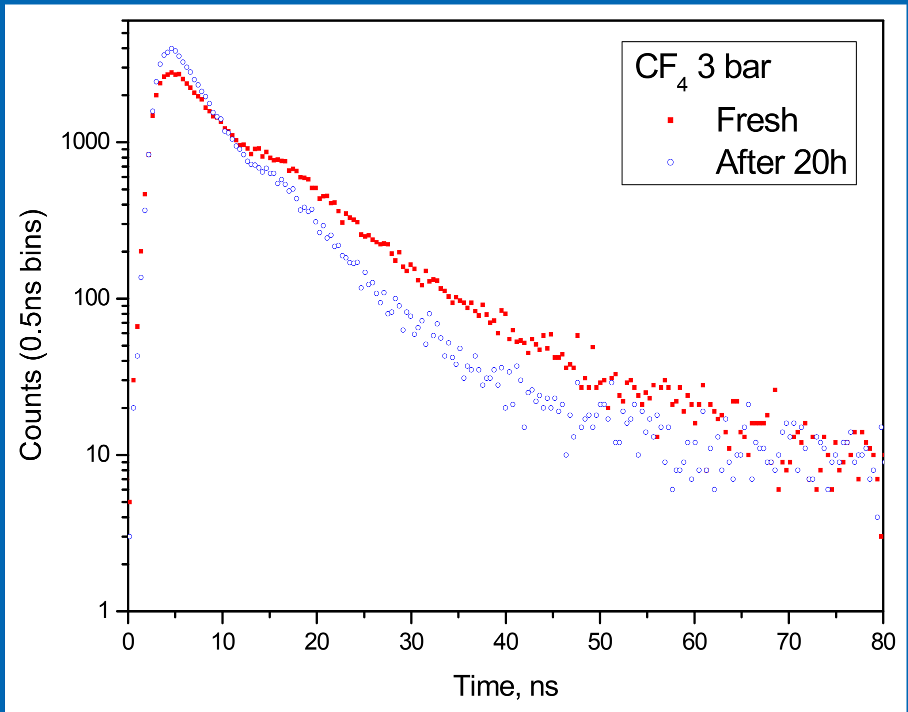


Mixture of 3 bar CF_4 + 2 bar He:

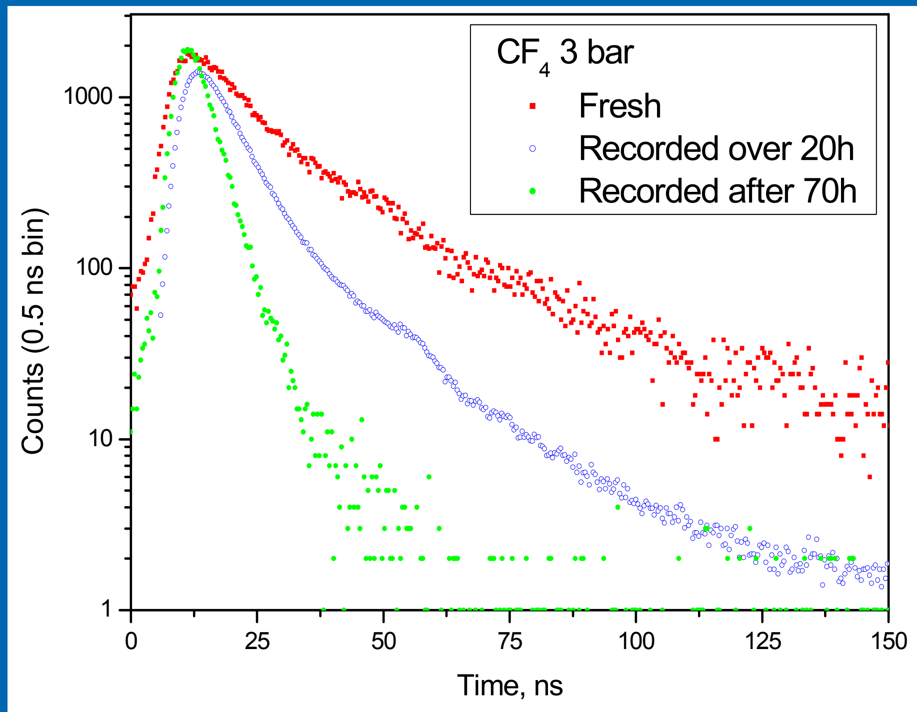
Helium has no effect on the time evolution of the CF_4 decay, both with and without electric field.

Gas aging studies: Time spectra

UV component



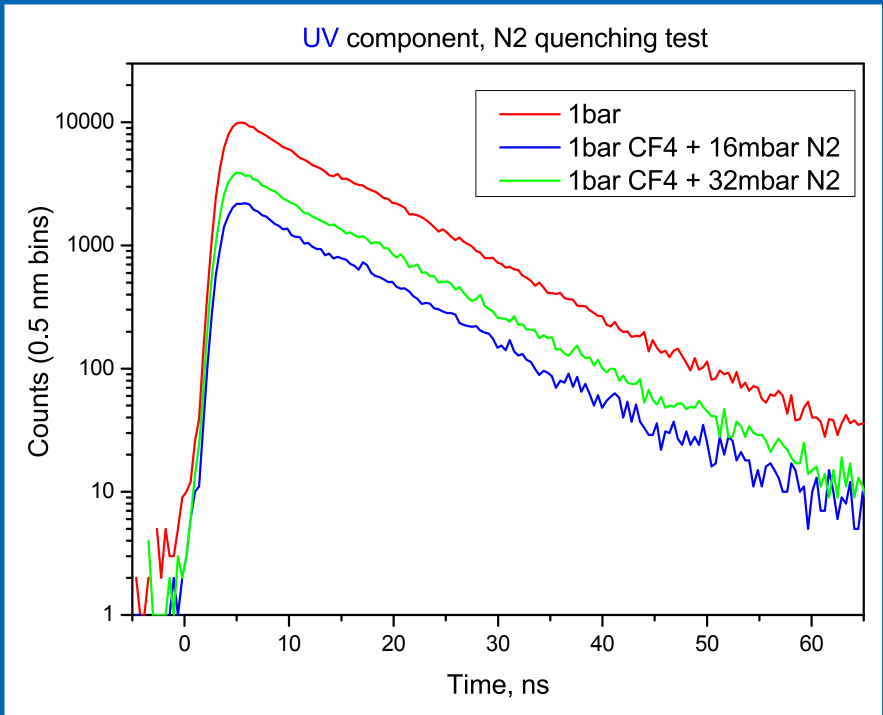
Visible component



Both components show significant aging!

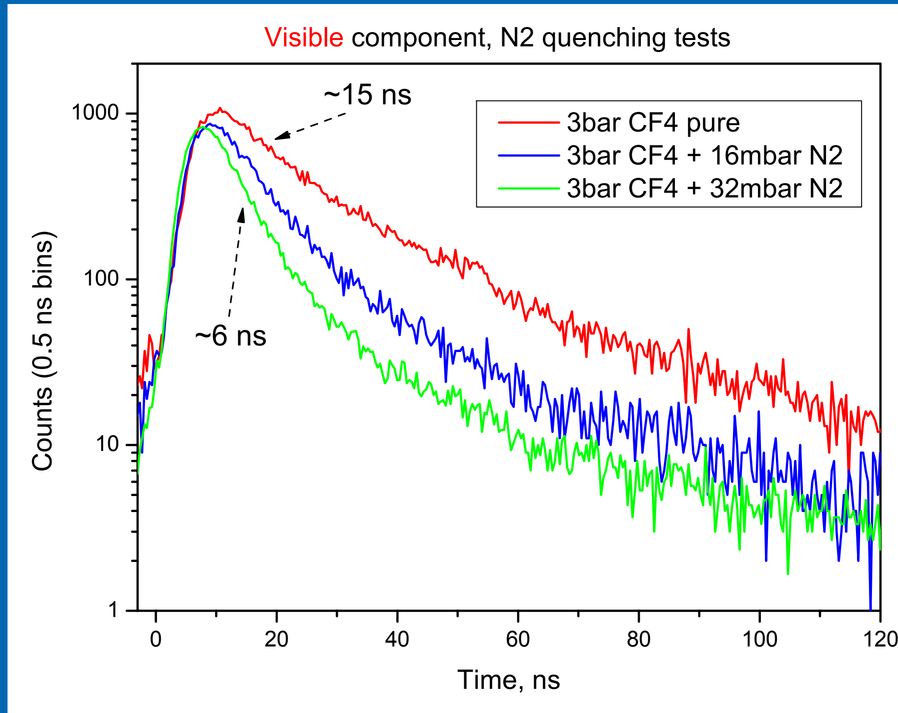
N_2 quenching

UV component



No effect!

Visible component



Strong effect!

Visible component is strongly affected by nitrogen admixtures!
Bad news, since CF_4 purifiers (effective) do not remove nitrogen.

Boiling:

N_2: 77 K

CF_4: 145 K

Thank you!