Fluorescence Yield in moist air by electron with Sr90

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Fluorescence technique for EAS observation

- Observed number of photons ($N_\gamma^{\rm obs}$)
  - $E = \dfrac{1}{1-\alpha}\displaystyle\int_0^X \left(\frac{{\rm d}E}{{\rm d}X}\right)_{\rm dep} {\rm d}X$
  - $\Delta N_\gamma^{\rm obs} = \left(\dfrac{{\rm d}E}{{\rm d}X}\right)_{\rm dep} \Delta X \displaystyle\sum_i \frac{\varphi(p,\lambda_i)}{h\nu_i} T(\lambda_i)\epsilon_{\rm det}(\lambda_i)$

φ_i : Fluorescence efficiency

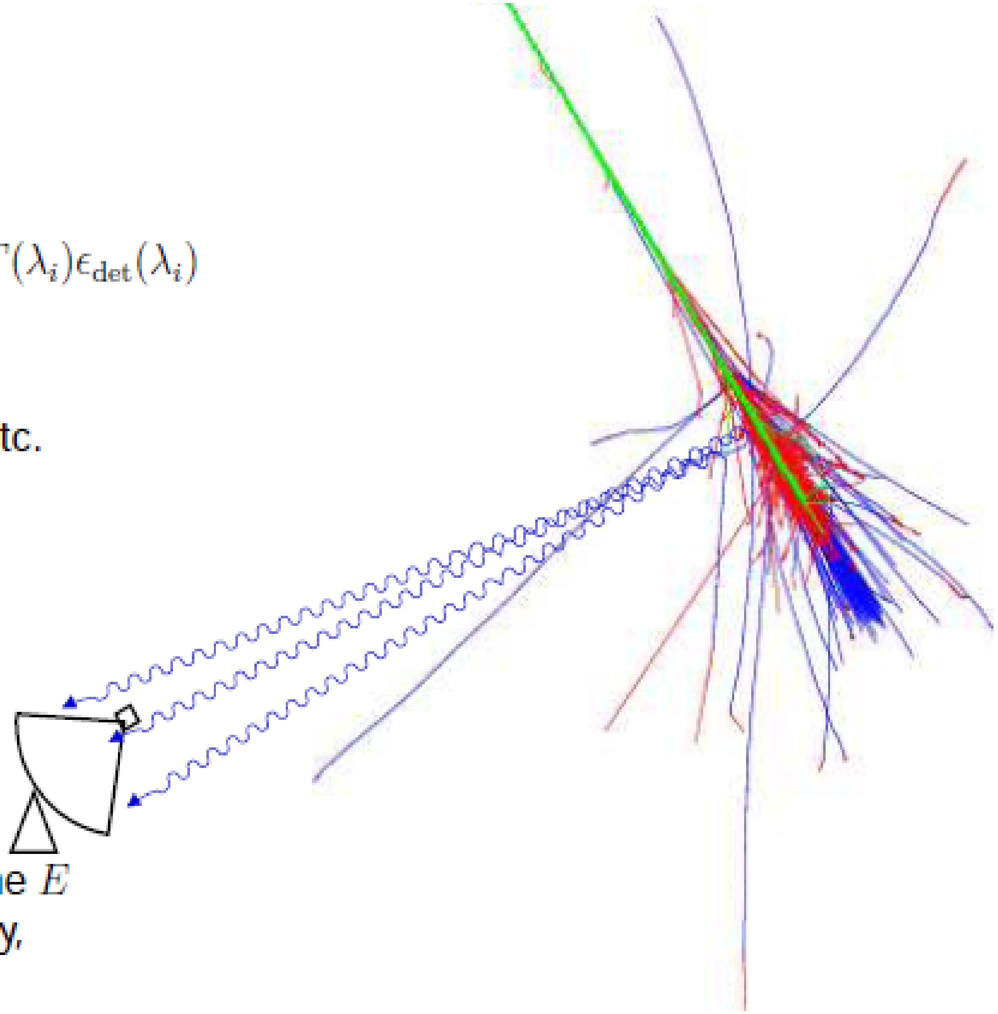
α : : Energy fraction to neutrinos etc.

T : Transmission in air

$\epsilon_{\rm det}$: detector efficiency

- Fluorescence yield

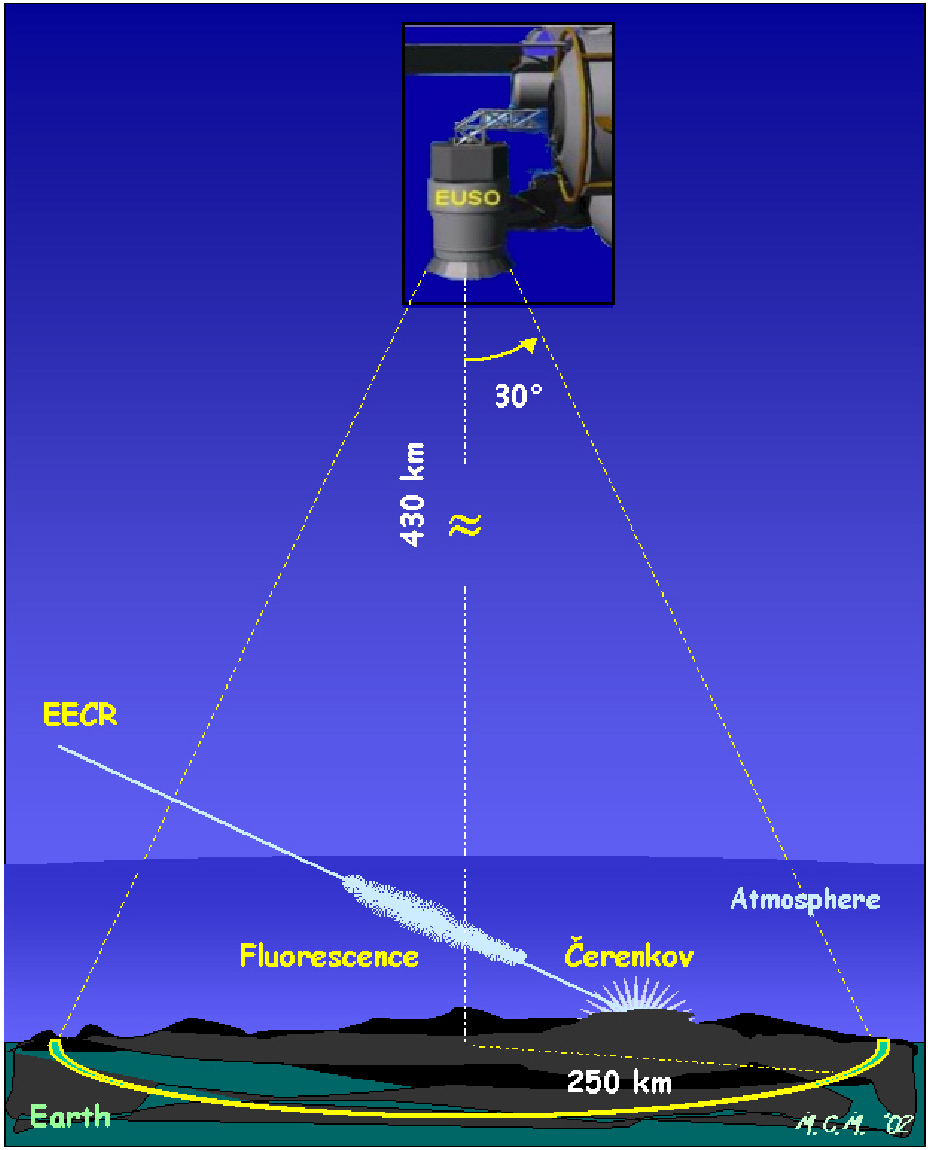
$$Y_i(E,p,T) = \rho(p,T)\frac{{\rm d}E}{{\rm d}X}(E)\frac{\varphi_i(p)}{h\nu_i}$$



Fluorescence yield is important to determine E for Fly's Eye, HiRes, Auger, Telescope Array, Ashra, JEM-EUSO, S-EUSO, ...

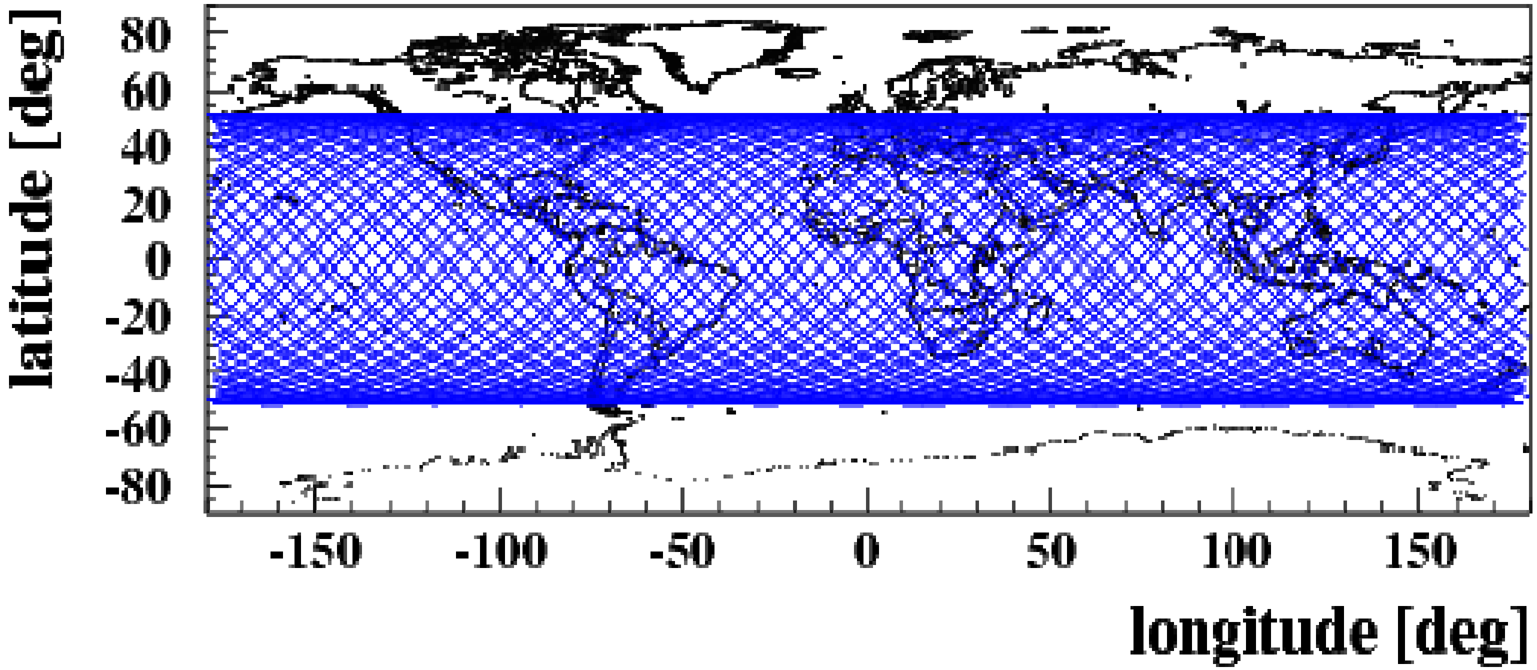
JEM-EUSO

- Particle Astronomy E>~5x10^{19} eV
- Fluorescence in air (300-400nm) will be detected with a 2.5m telescope on ISS
- ~1000 events of UHECR will be observed in mission period
- UHE-neutrino
- Launch in ~2015 is foreseen



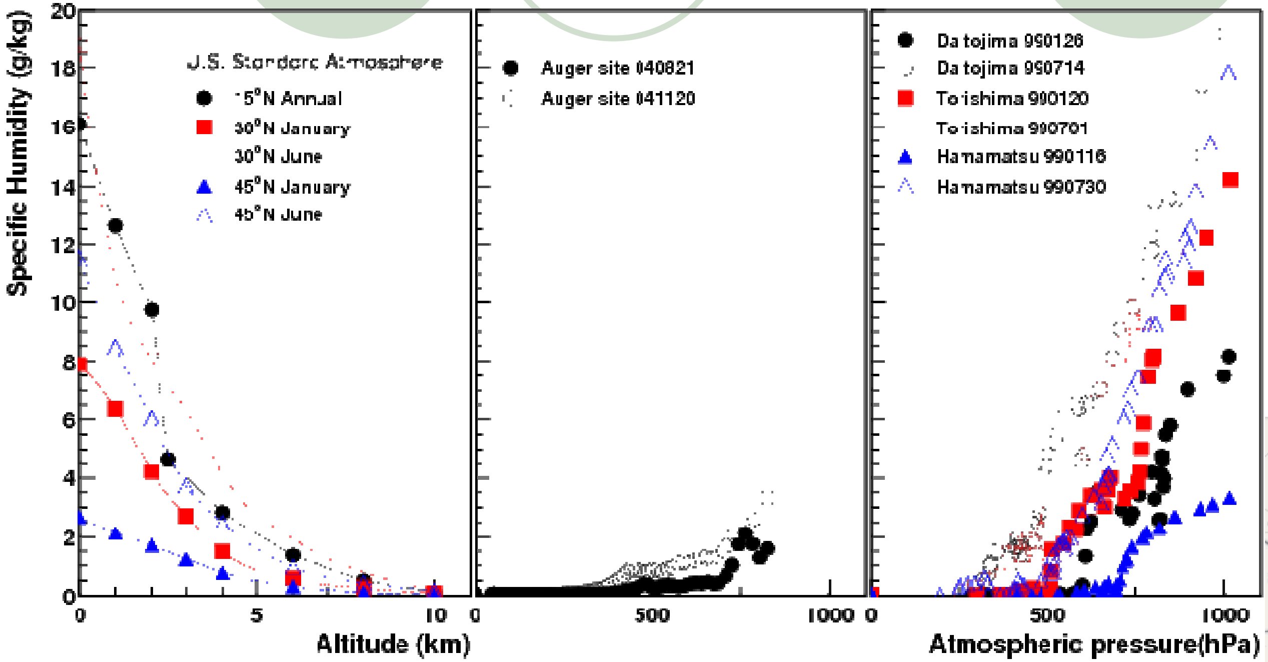
Effect of humidity on fluorescence measurement?

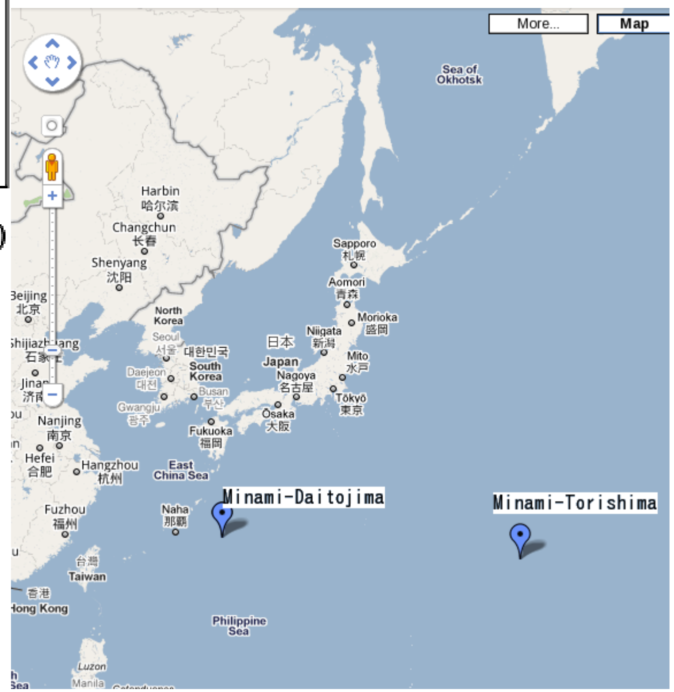
ISS orbit



Most of EAS will be observed above sea for space-based experiment like JEM-EUSO

Humidity data



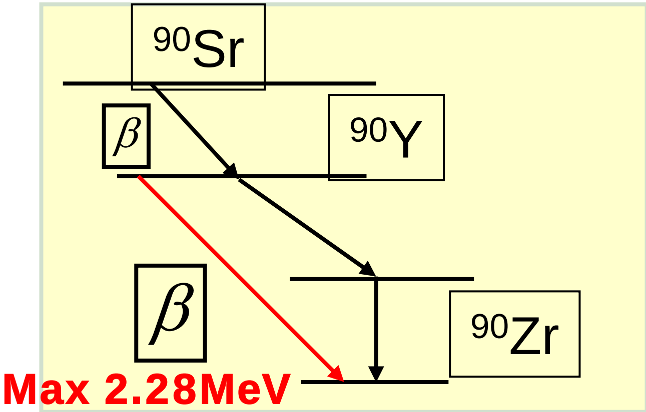


Chamber

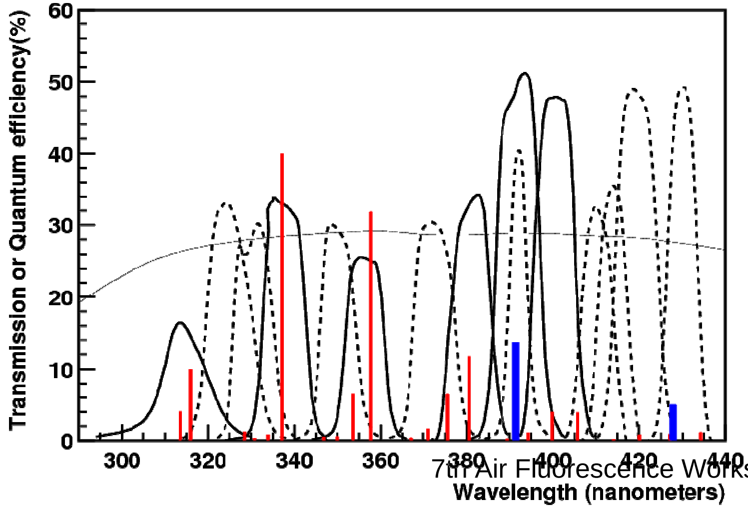
Filter CW：337nm、358nm、391nm、380nm、370nm、313nm、330nm、430nm、325nm、400nm

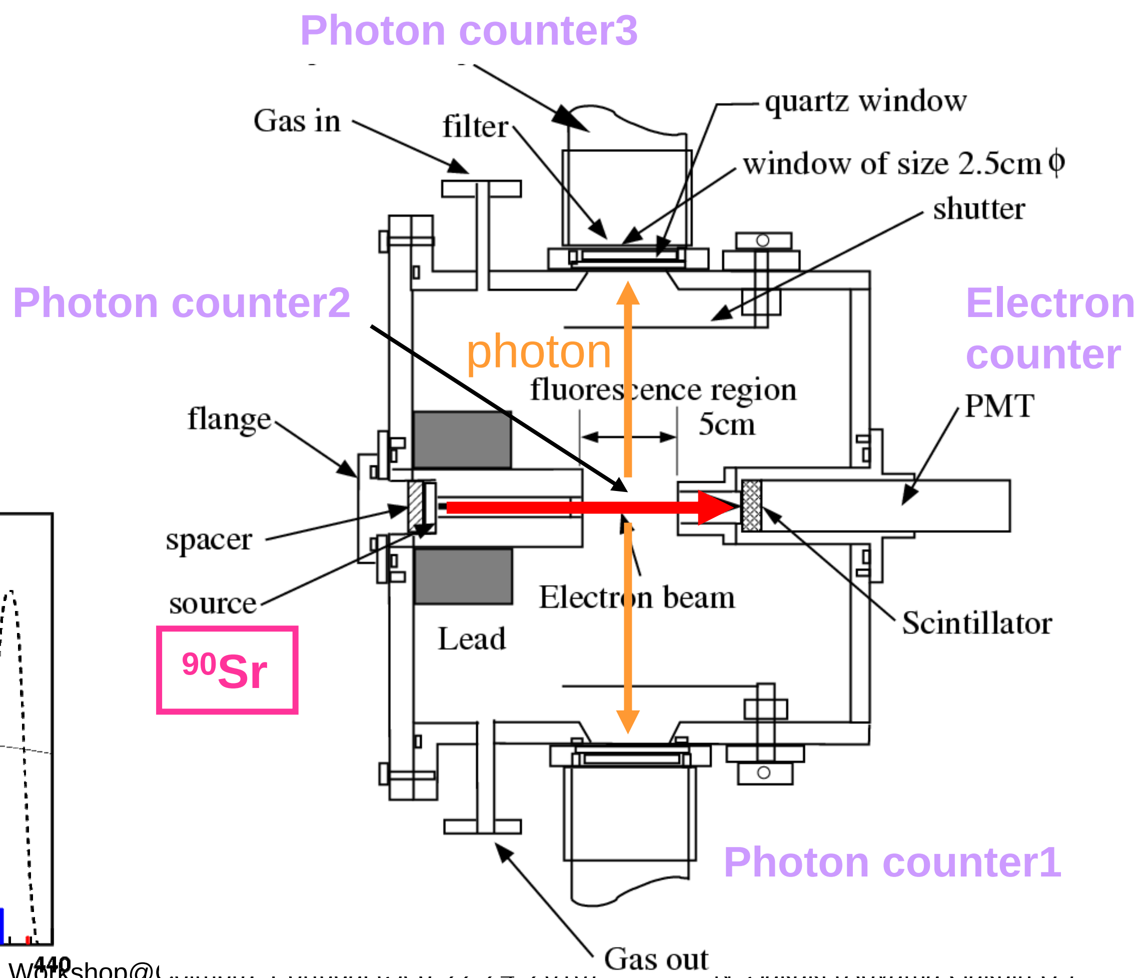
N_2 second positive band

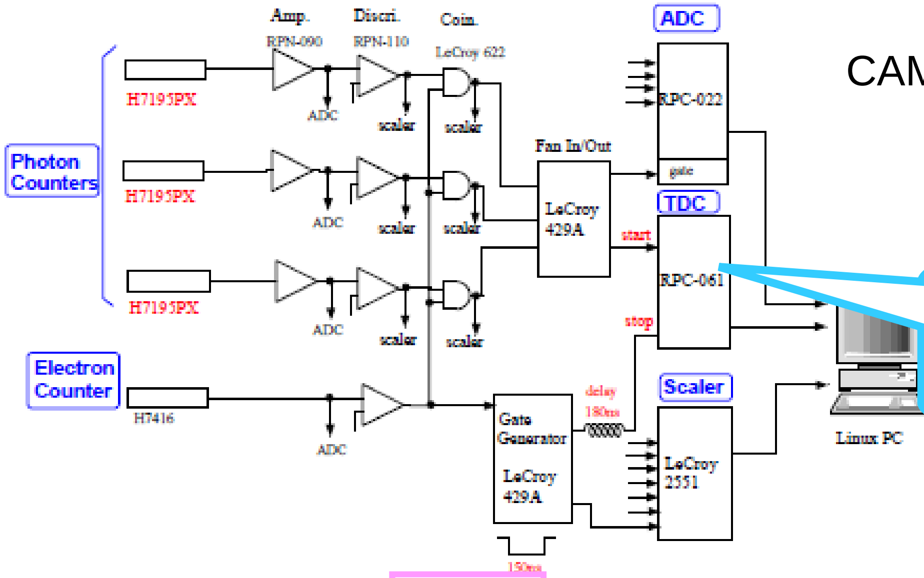
N_2^+ first negative band



Filter transmission

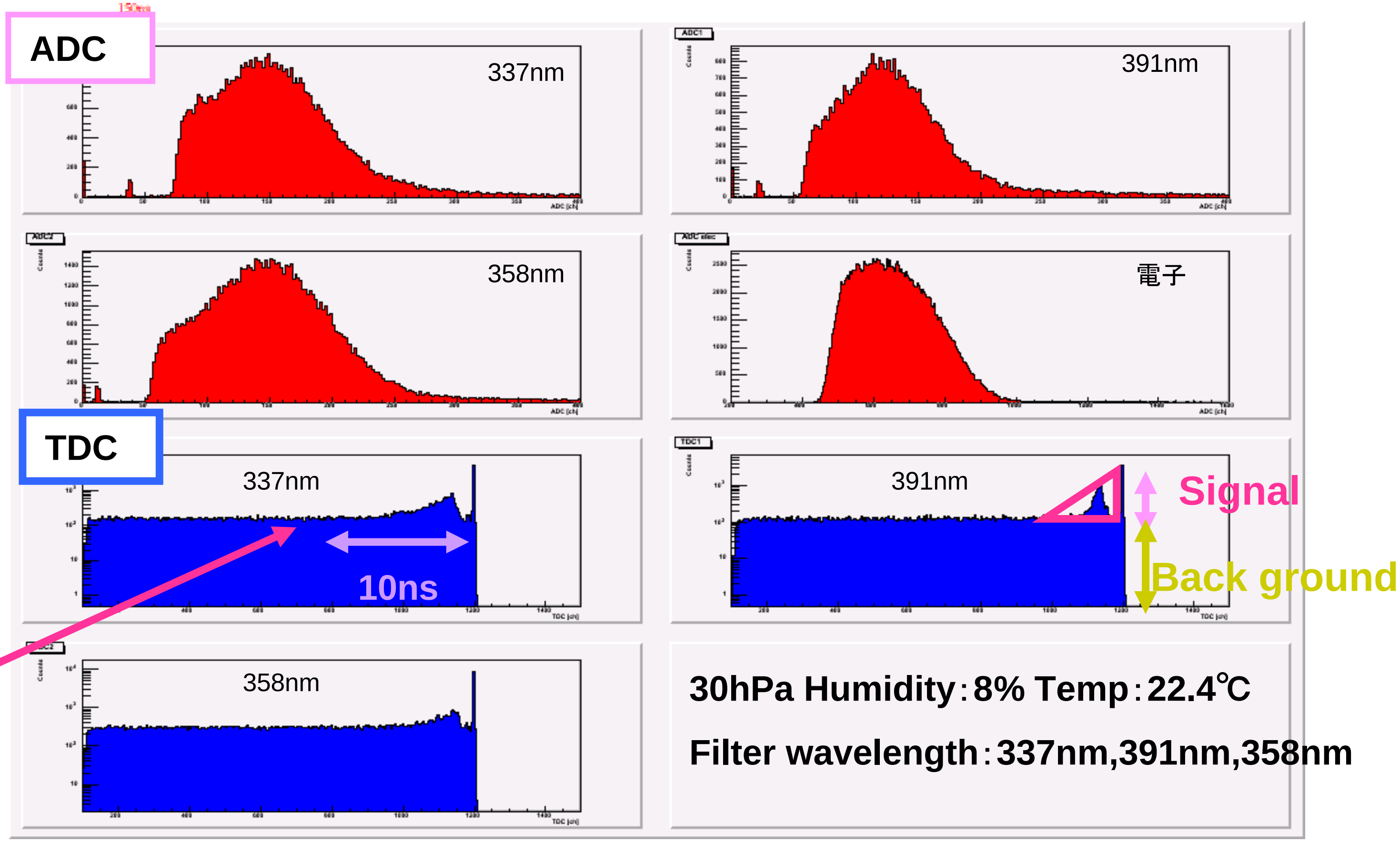






CAMAC+NIM system

TDC Delay of photon signal from electron signal



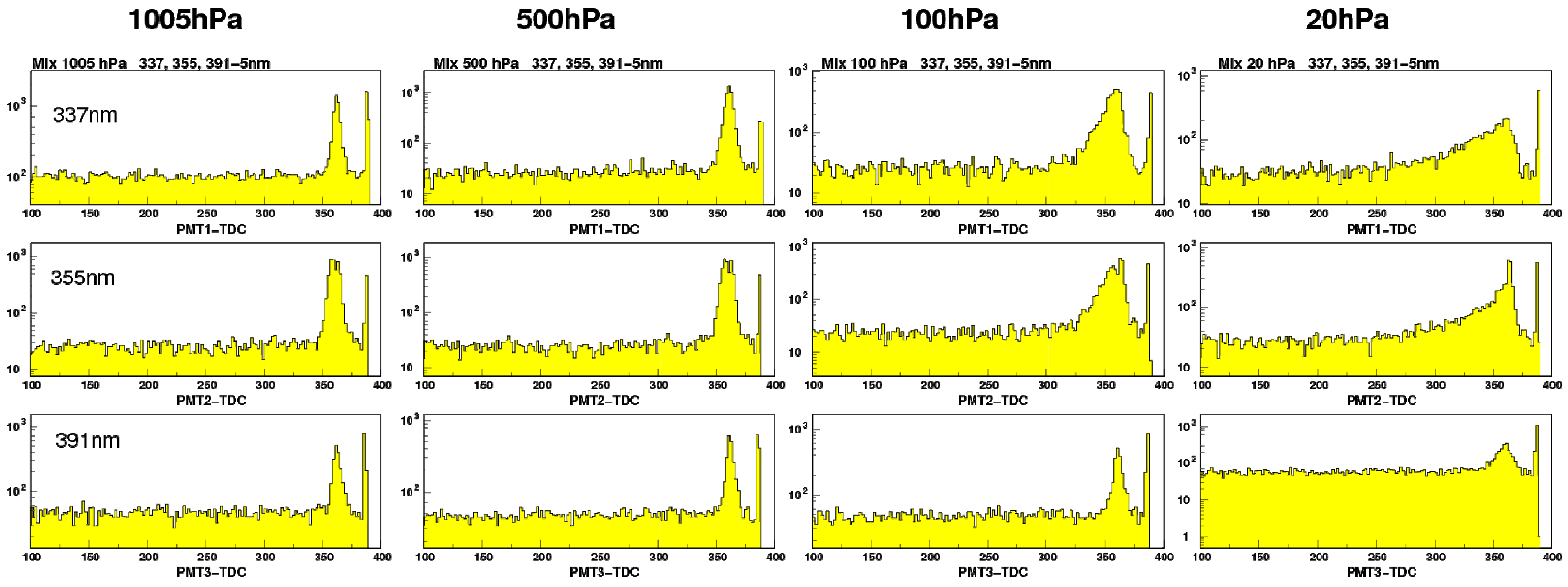
τ :lifetime

$$e^{a+\frac{t}{\tau}}+c$$

30hPa Humidity：8% Temp：22.4℃

Filter wavelength：337nm,391nm,358nm

TDC data for various pressures



Fluorescence yield

$$\varepsilon = \frac{N}{I \times a \times \Omega \times \eta \times f \times \mathrm{Q.E.} \times \mathrm{C.E.}}$$

ε:	Photon Yield per unit length [/m electron]
I:	Total number of electrons
N:	Total number of signal counts
a:	Length of the fluorescence portion
Ω:	Solid angle of the PMT
η:	Quartz window transmission
f:	filter transmission
Q.E.:	Quantum efficiency of the PMT
C.E.:	Collection efficiency of the PMT

P' (reference pressure)

$$\frac{1}{\tau} = \frac{1}{\tau_r} + \frac{1}{\tau_c}$$

τ : total lifetime
τ_r: lifetime for radiation
τ_c: lifetime for collisional quenching

P': pressure for $\tau_r = \tau_c$

$$\varepsilon = \frac{C\rho_{N_2}}{(1+\frac{P}{P'})}$$

$$\frac{1}{\tau} = \frac{1}{\tau_r}(1+\frac{P}{P'})$$

P', C, τ_r, τ_c will be determined

C: fitting constant

P' for moist air

$$\frac{1}{P'} = (1-\frac{P_w}{P})\frac{1}{P'_{dryair}} + \frac{P_w}{P}\frac{1}{P'_{H_2o}}$$

P_w: Water vapor pressure

P'_{dryair}: P' for dry air

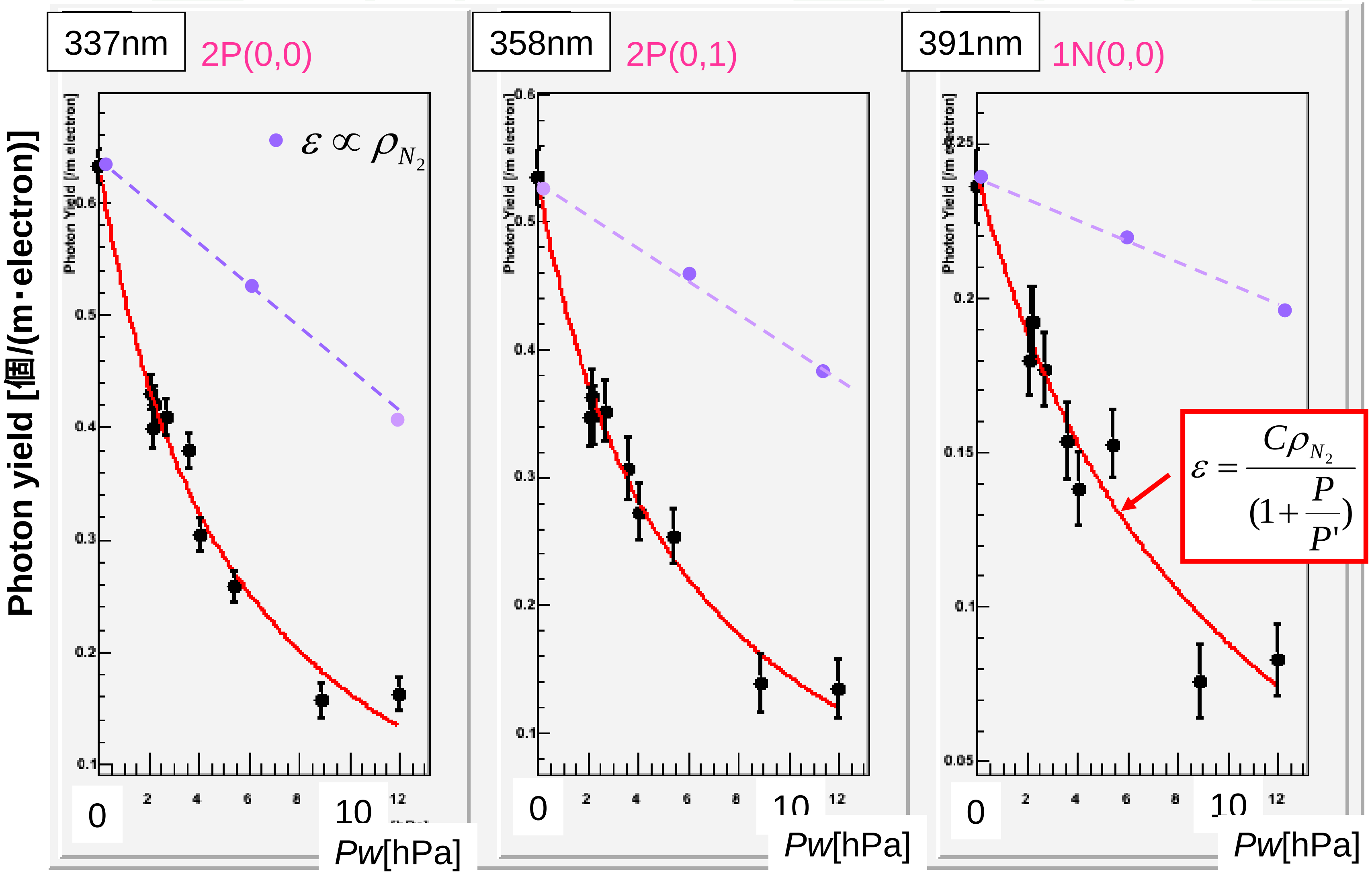
P'_{H_2O} will be determined.

Measurement

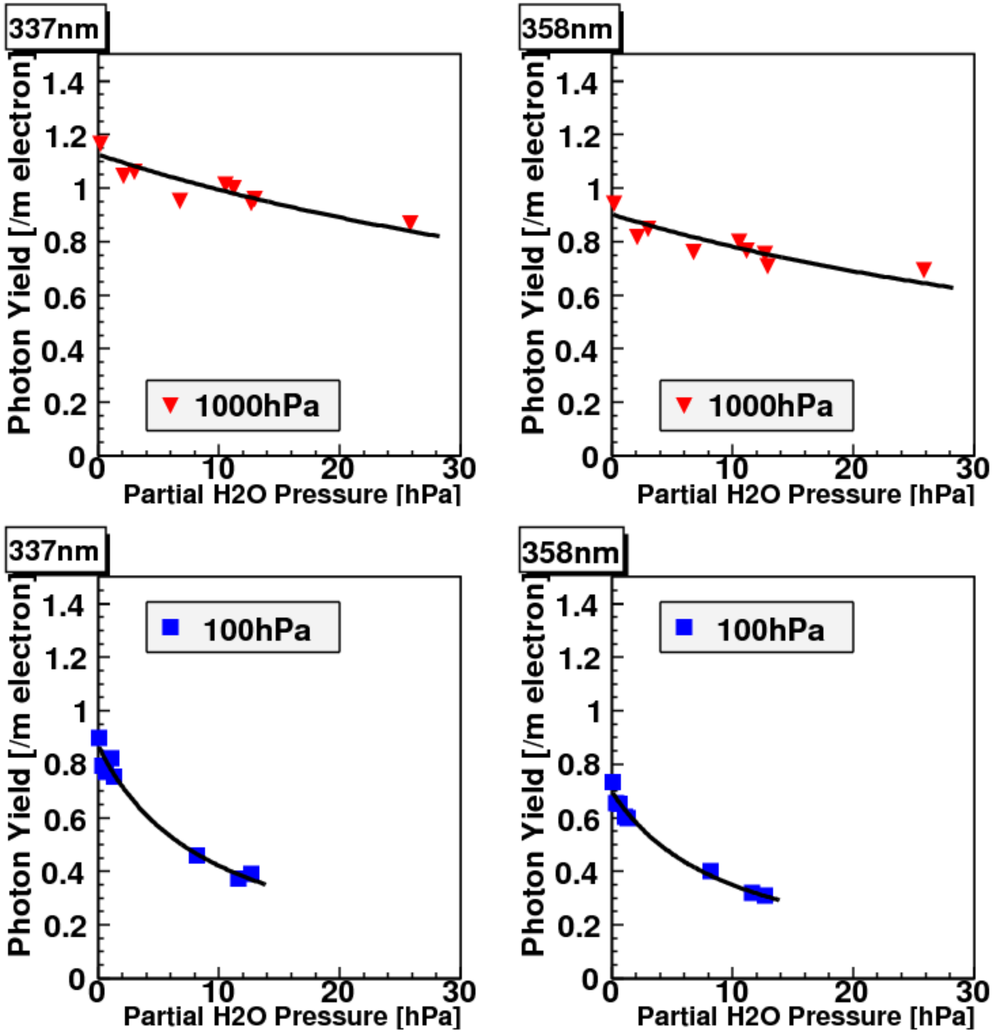
- Same chamber as for dry air measurement used.
- Laboratory air was used and humidity was given/removed by passing through water/silica gel.
- Filters (313,325,330,337,358,370,380,391,400,430nm)
- Total pressure was fixed at 30hPa (100,1000hPa) and Relative humidity was changed in 0-65%.
- Temperature ~20C^{o}
- P' was determined from yield and lifetime data.

$$\frac{1}{P'} = (1 - \frac{P_w}{P})\frac{1}{P'_{dryair}} + \frac{P_w}{P}\frac{1}{P'_{H_2o}}$$

Photon yield vs. water vapor pressure $P_w(P_{total}=30[hPa])$

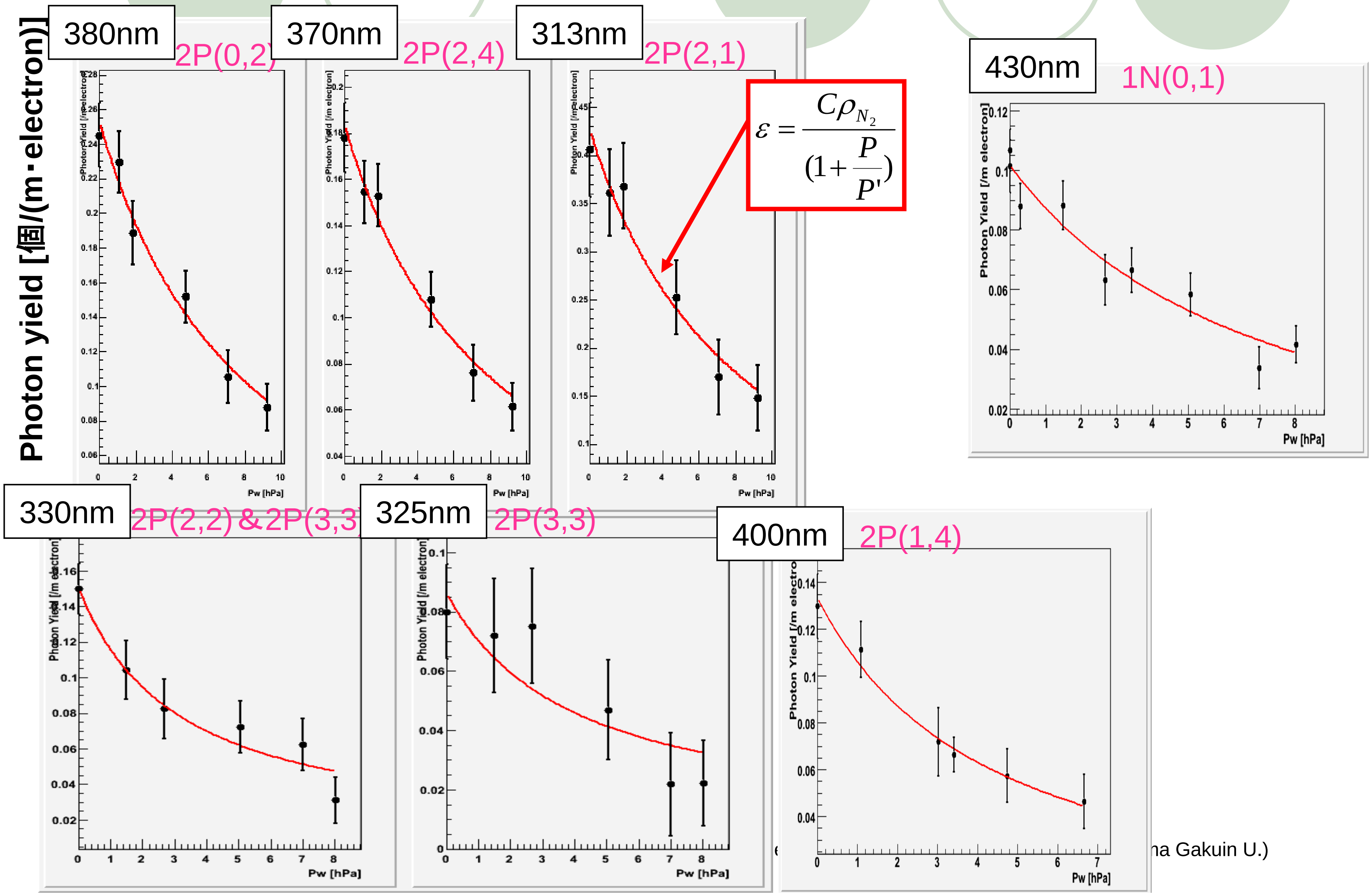


Photon yield vs. water vapor pressure P_w (P_{total}=100,1000[hPa])



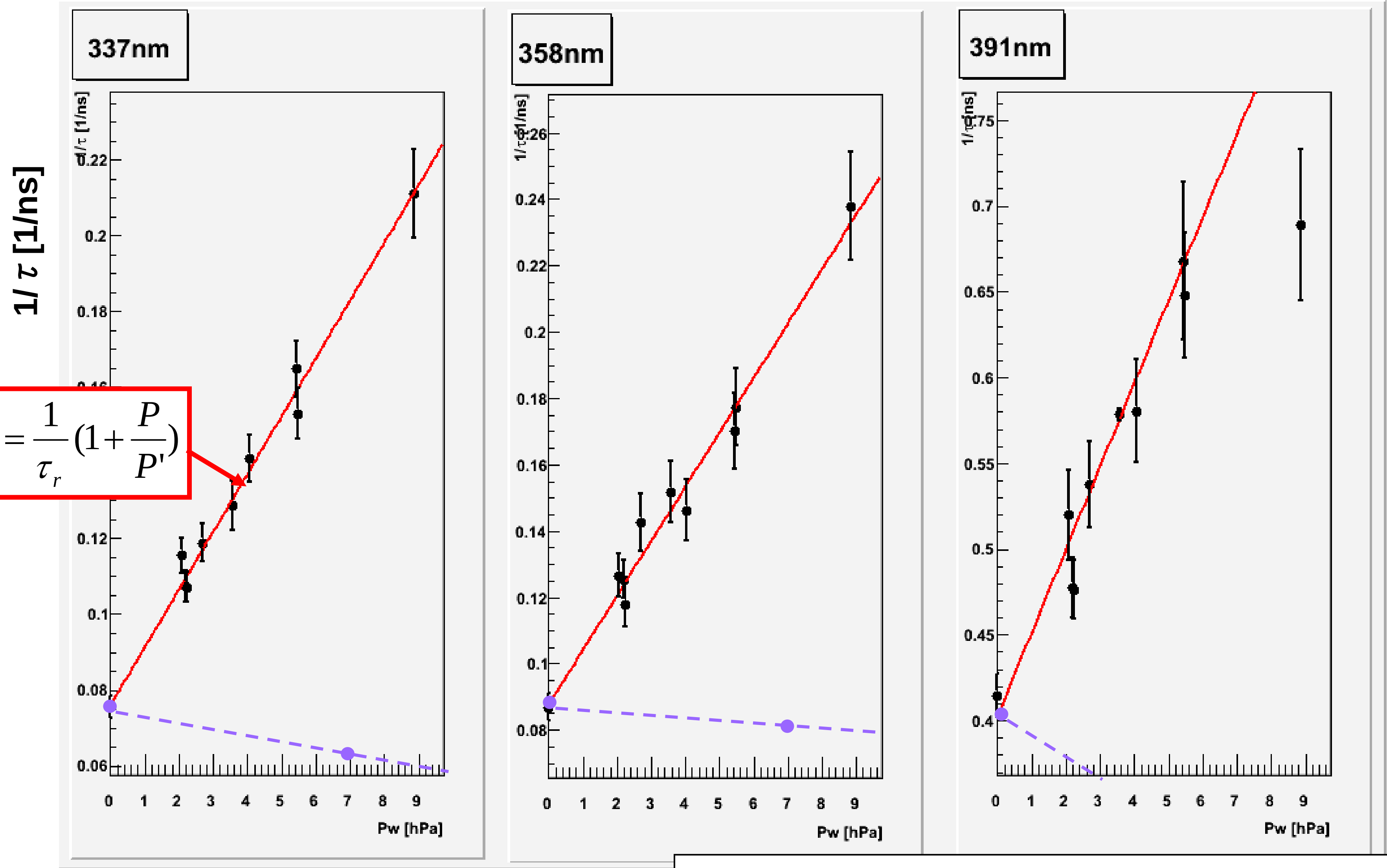
Photon yield vs. P_w(P_{total}=30[hPa])

(313nm,325nm,330nm,370nm,380nm,400nm,430nm)



$1/\tau$ vs. P_w (P_{total}=30[hPa])

$$\frac{1}{P'} = (1 - \frac{P_w}{P}) \frac{1}{P'_{dryair}} + \frac{P_w}{P} \frac{1}{P'_{H_2O}}$$

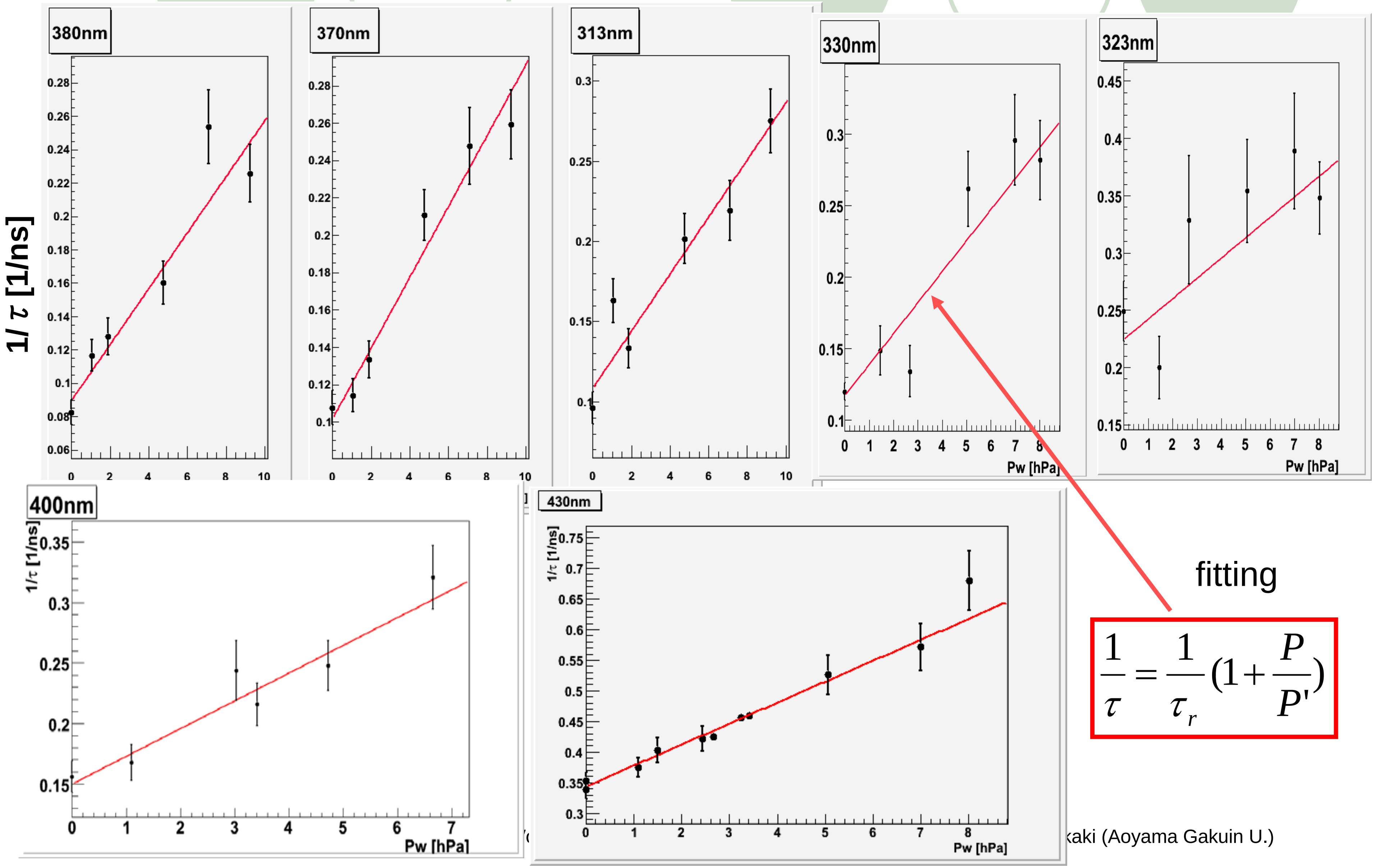


$$\frac{1}{\tau} = \frac{1}{\tau_r}(1 + \frac{P}{P'})$$

● : expected lifetime from N2 content

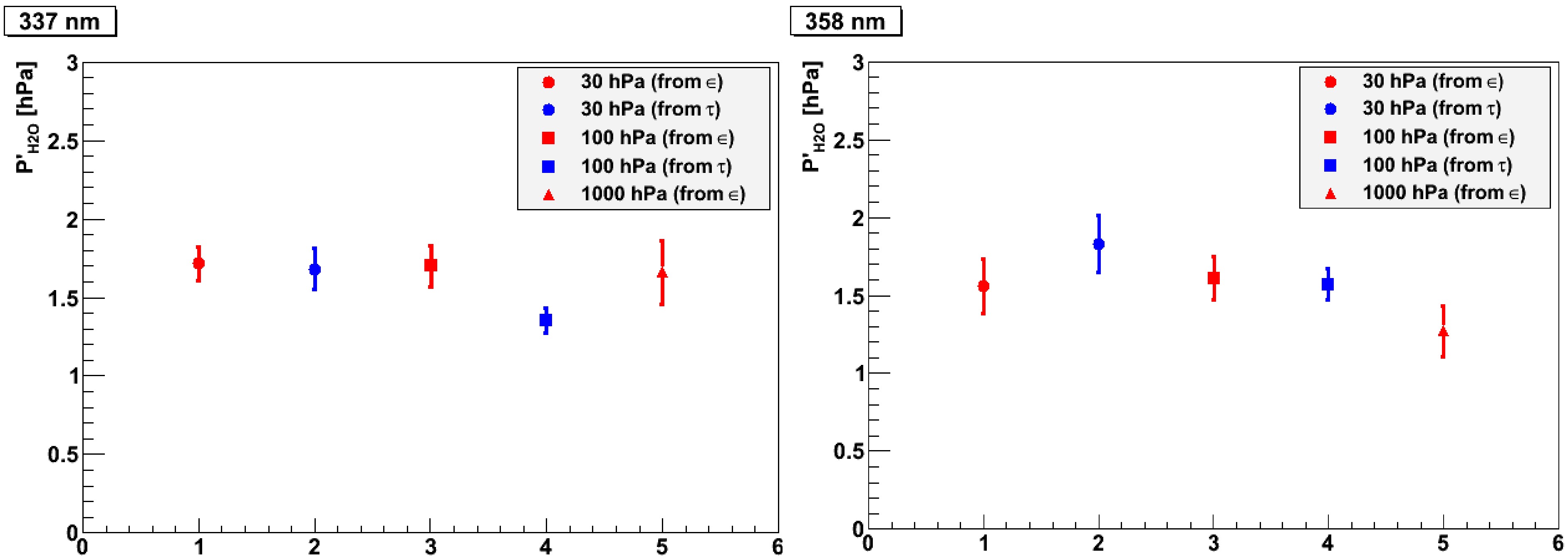
$1/\tau$ vs. P_w (P_{total}=30[hPa])

(313nm,323nm,330nm,370nm,380nm,400nm,430nm)

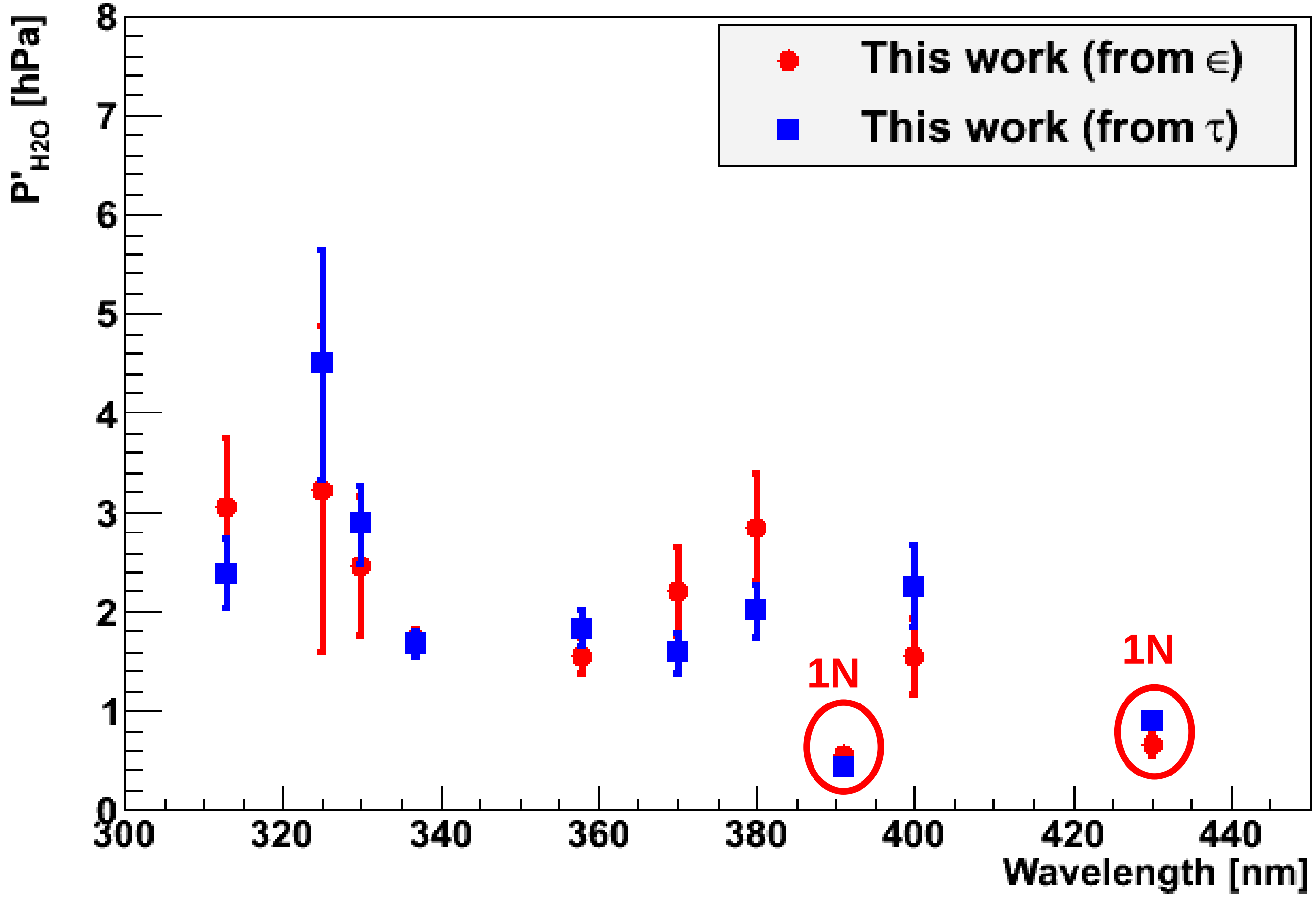


$$\frac{1}{\tau} = \frac{1}{\tau_r}(1+\frac{P}{P'})$$

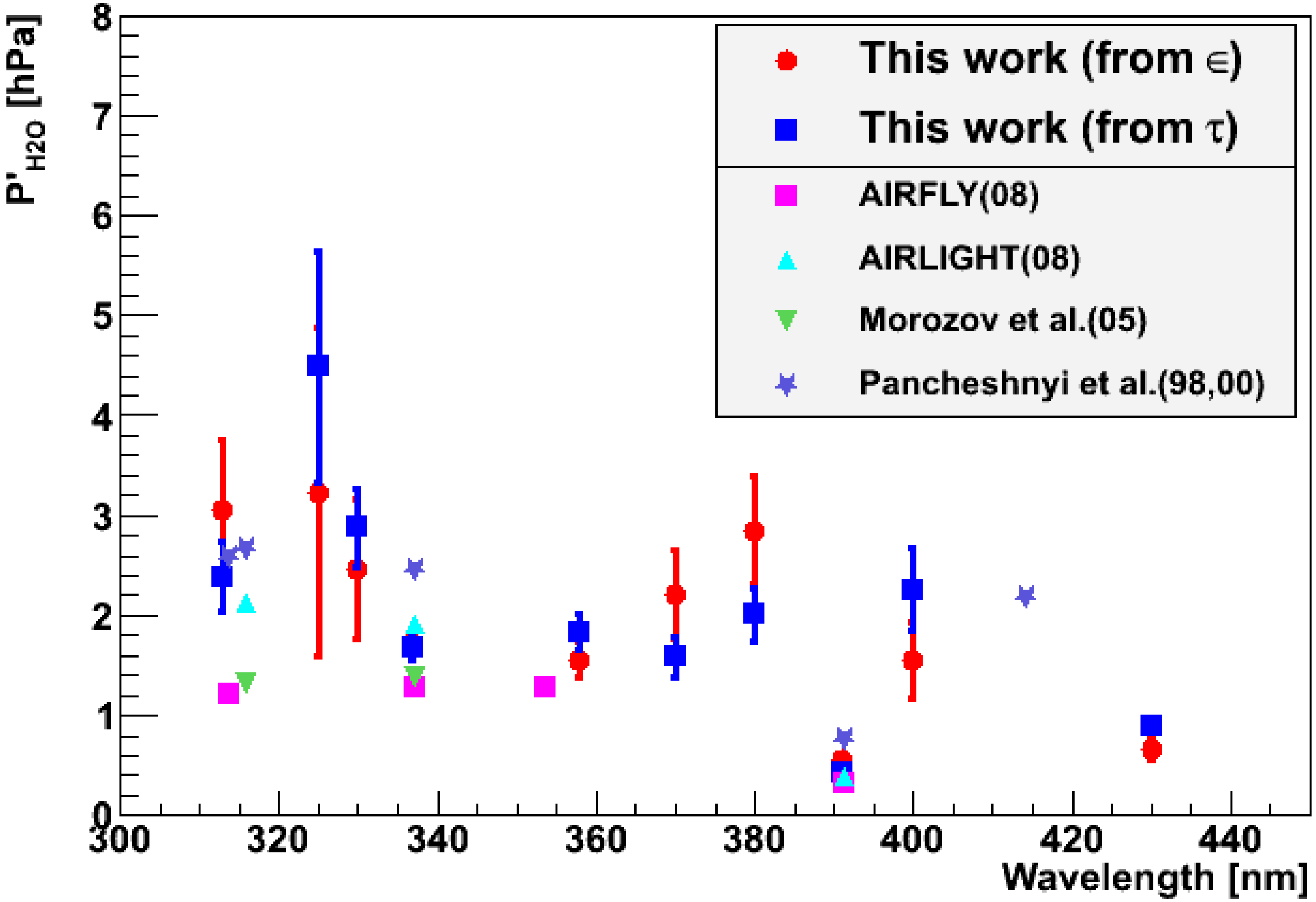
P'$_{H2O}$ for 337nm and 358nm



P'_{H2O} (P_{total}=30hPa)

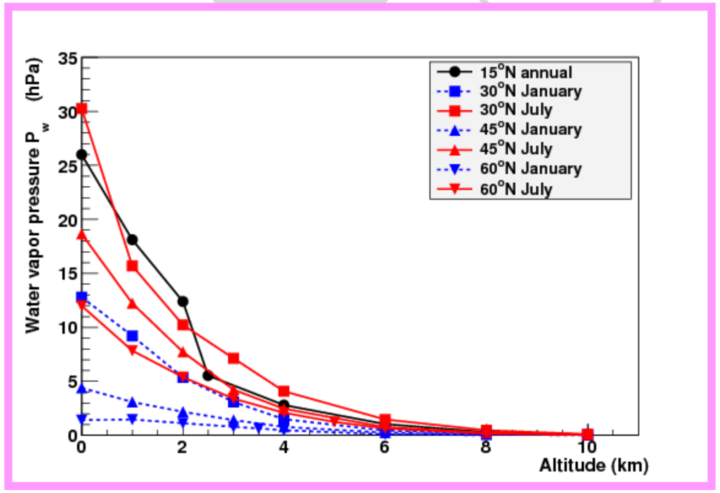


P'_{H2O}

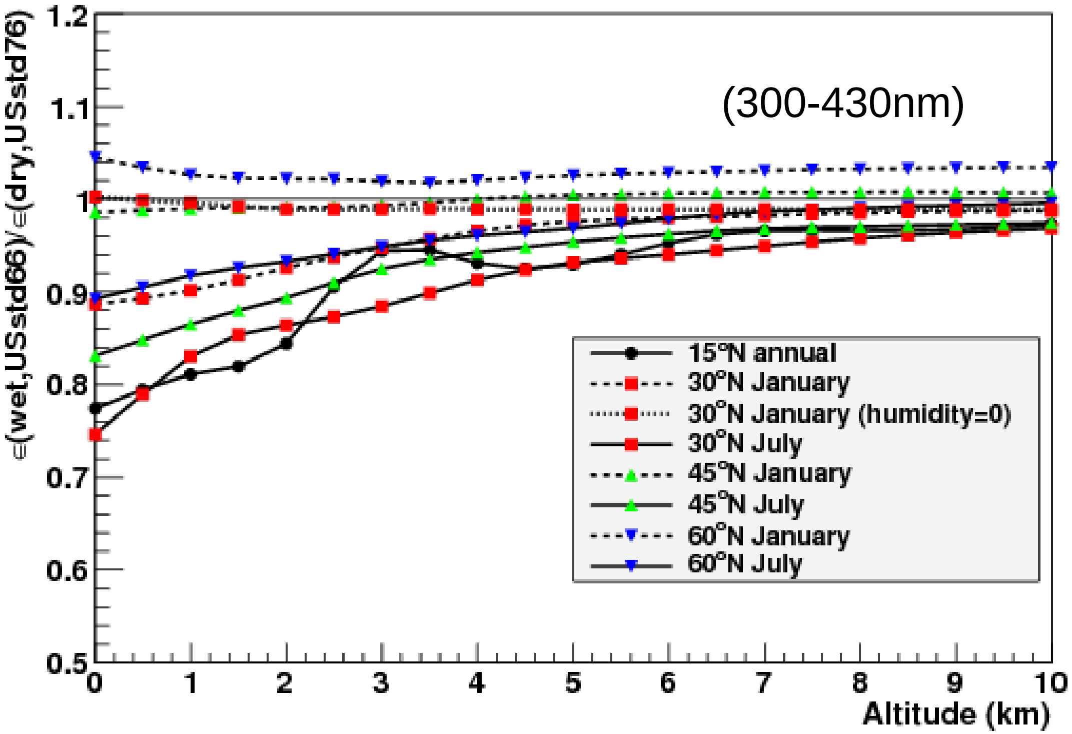


P'H2O [hPa]
8
7
6
5
4
3
2
1
0
300
320
340
360
380
400
420
440
Wavelength [nm]
This work (from ∈)
This work (from τ)
AIRFLY(08)
AIRLIGHT(08)
Morozov et al.(05)
Pancheshnyi et al.(98,00)

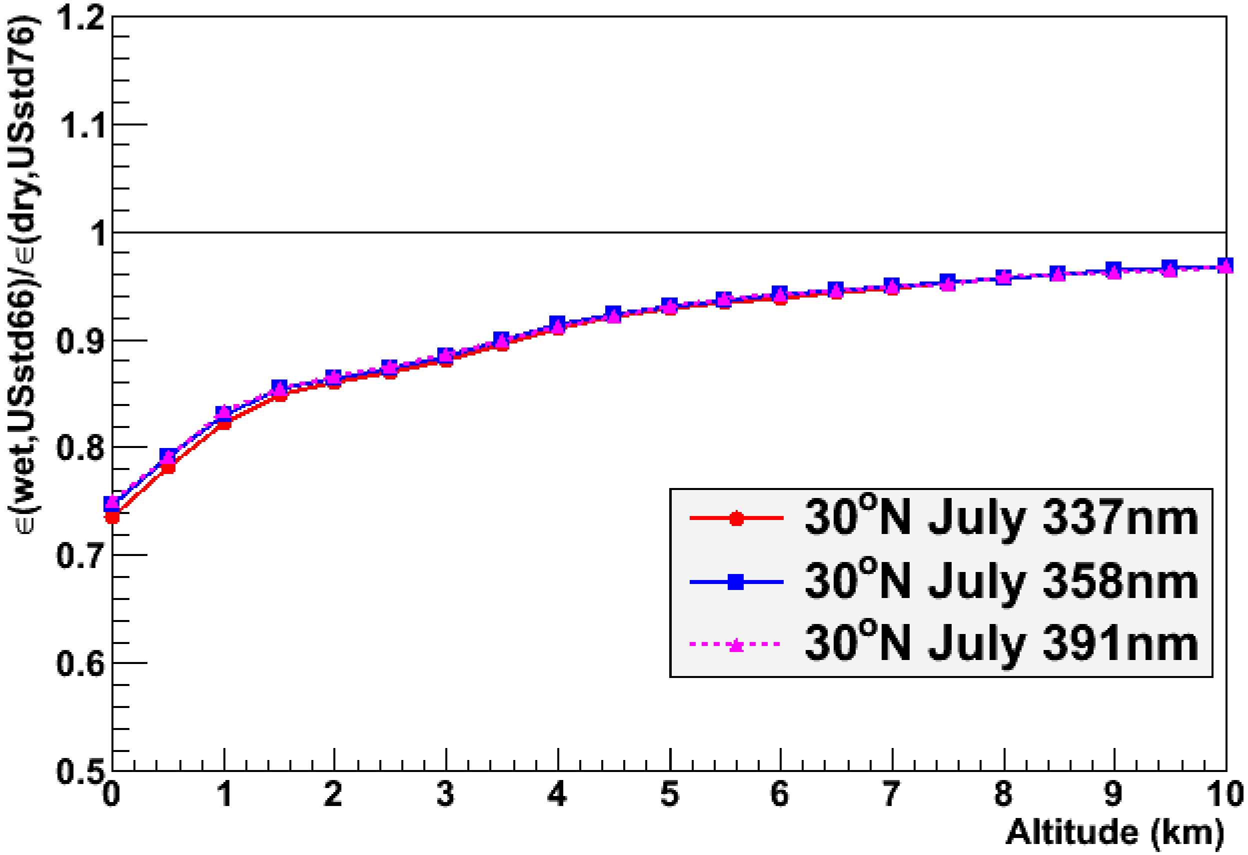
Humidity dep. of Yield (US std atm.66)



$$\varepsilon = (\frac{dE}{dx})_{0.85MeV} \frac{\varphi^0 \rho_{N_2}}{h\nu(1+\rho R_g \sqrt{293T} / p'_{20})}$$

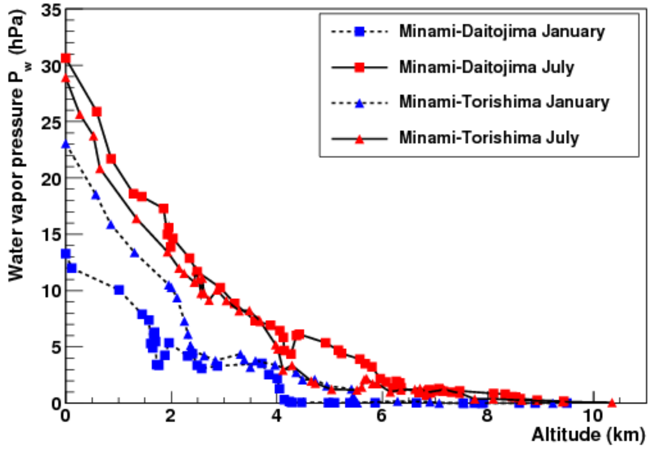


Humidity dep. of Yield (US std atm.66)

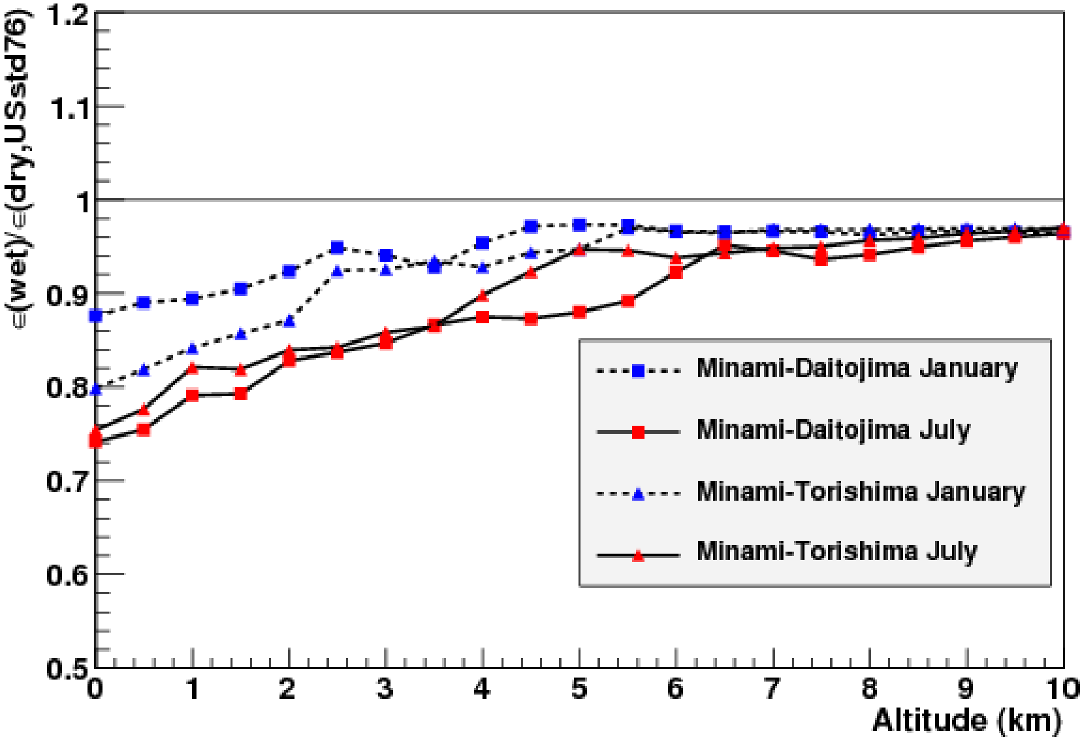


Humidity dep. of Yield 2

(application for climate data of Minami-Torishima and Minami-Daitojima)



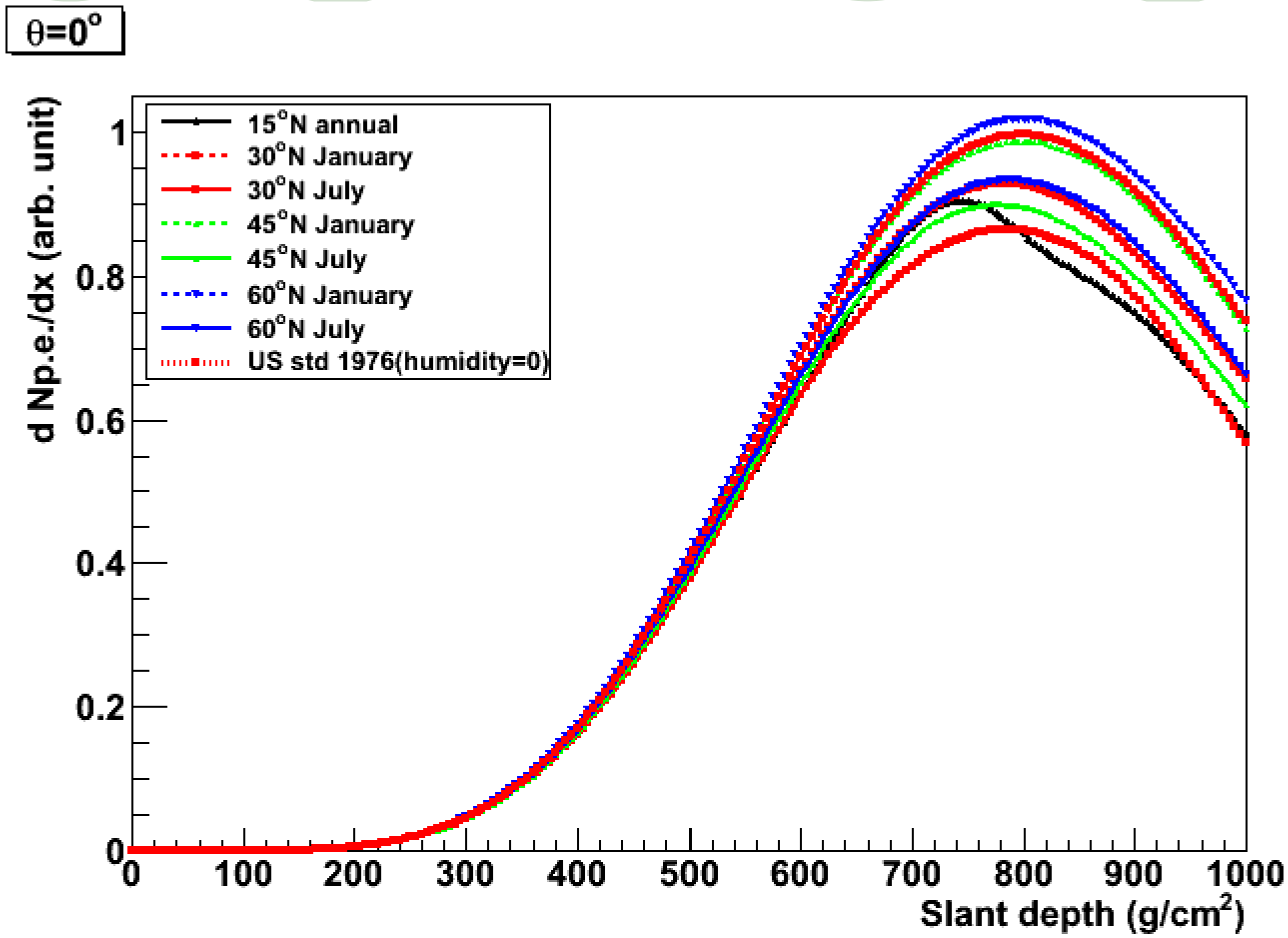
Data from Japan Metrological Agency(1999)



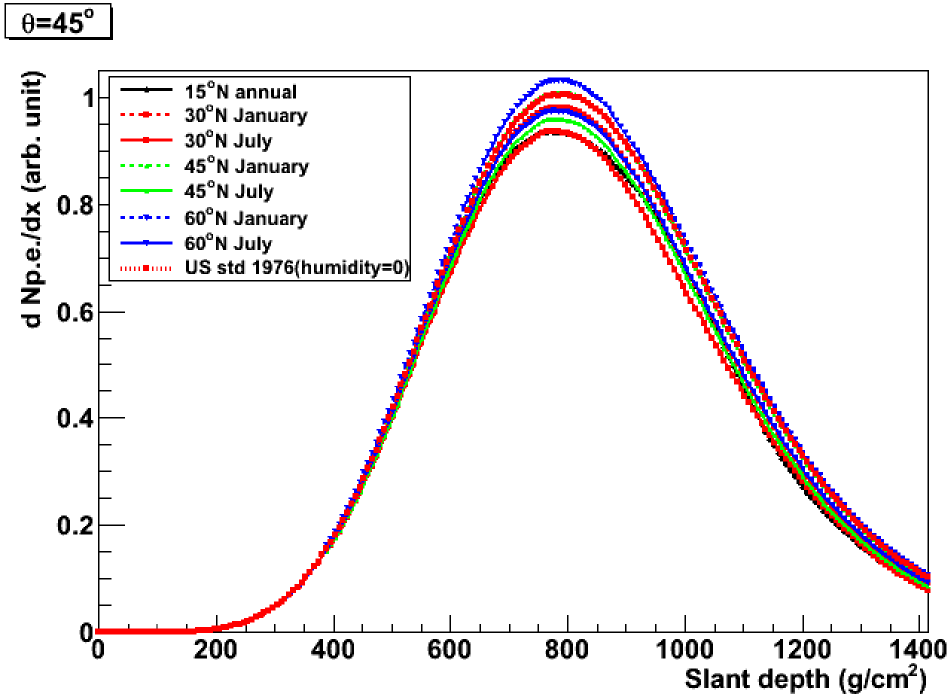
Condition of Air shower simulation

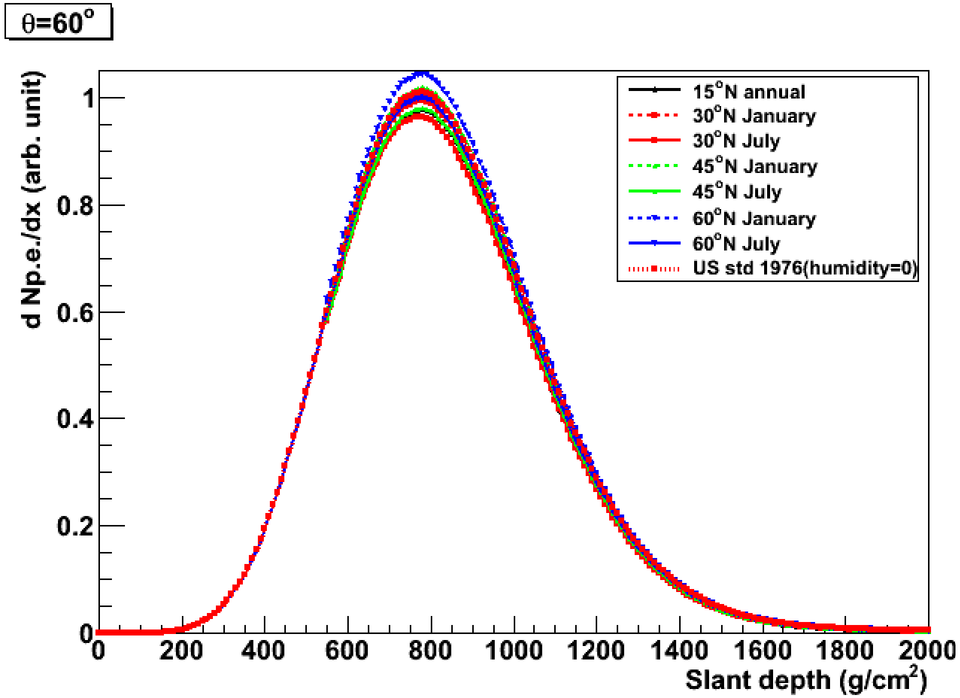
- CORSIKA6.02+QGSJET1
- $E=10^{20}$ eV proton
- Zenith angle=0,45,60^{o}
- Averaged shower curve of 30 showers for each zenith angle
- Only Rayleigh attenuation is taken into account
- Observation from ISS height (430km)
- US standard 1966 atmosphere and Japanese island atmosphere (only for fluorescence yield calculation)

Vertical shower (US std atm.66)

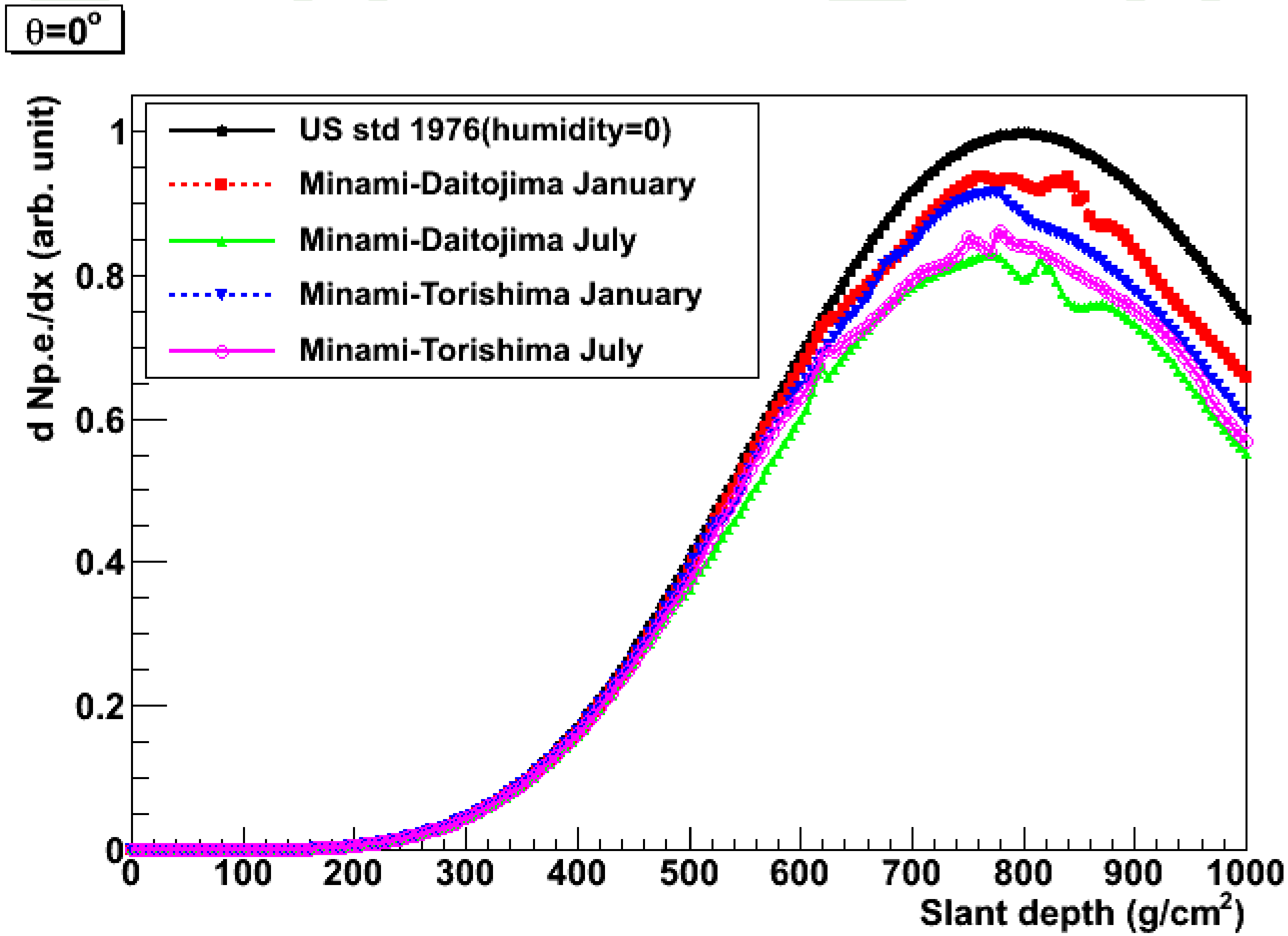


Inclined shower (US std. atm. 66)

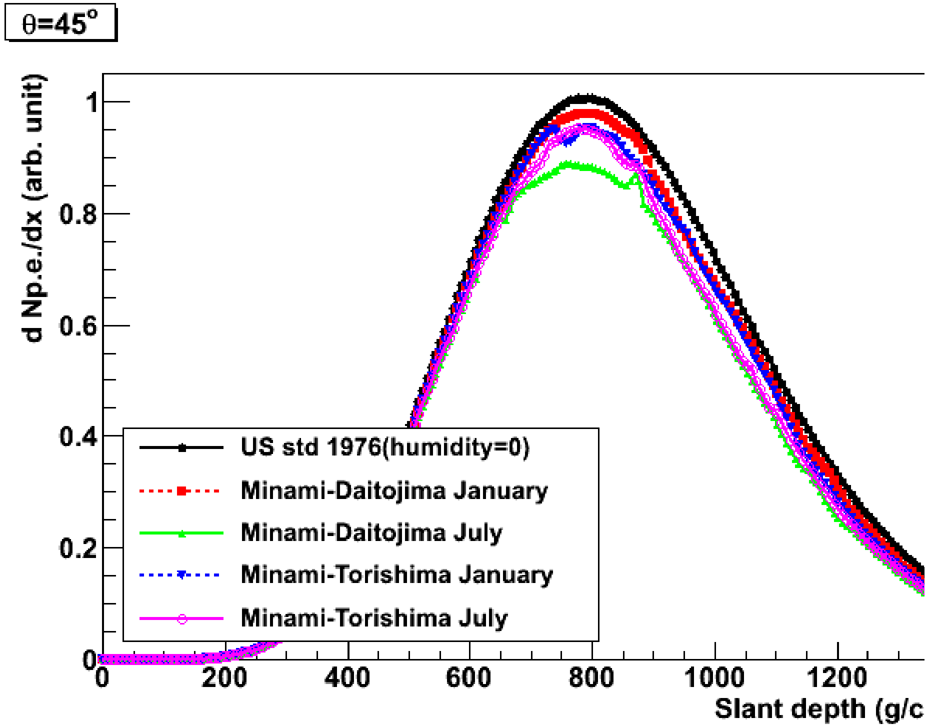


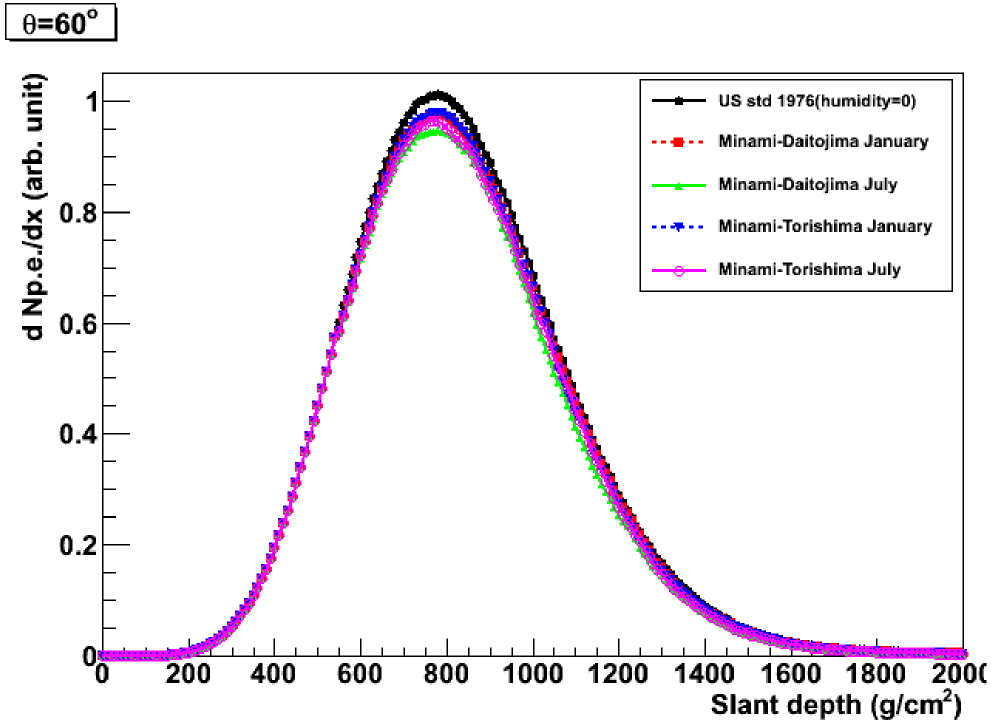


Vertical Shower (above sea)



Inclined shower (above sea)





Summary

- In order to study the effect on EAS observation with fluorescence, we have measured fluorescence yield and lifetime for various humidity in10 bands in 300-430nm.
- Yield decreases down to 80% with increasing humidity.
- Reference pressure P'_{H2O} is 0.5-1hPa for 1N bands, and 1-3hPa for 2P bands. P'_{H2O} from yield and liftime are consistent with each other. And they agree with those by other experiments.
- Fluorescence yield at ground decreases by 25% at lower latitude in summer for US standard atmosphere 1966 and real ocean atmosphere.
- For EAS observation, the number of observed photons from Nmax decreases by ~15% (vertical), ~10%(45^{o}) and ~5%(60^{o}).

  ⇒ Since most EAS observed by JEM-EUSO are ~60^{o}, humidity effect may be small. For more detailed evaluation, it is necessary to include detector response and to use global climate data.

- Backup

Temperature

Minami-Daitojima 25º49'N 131º14'E
Minami-Torishima 24º17'N 153º59'E