T2K muon monitors

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for T2K muon monitor group

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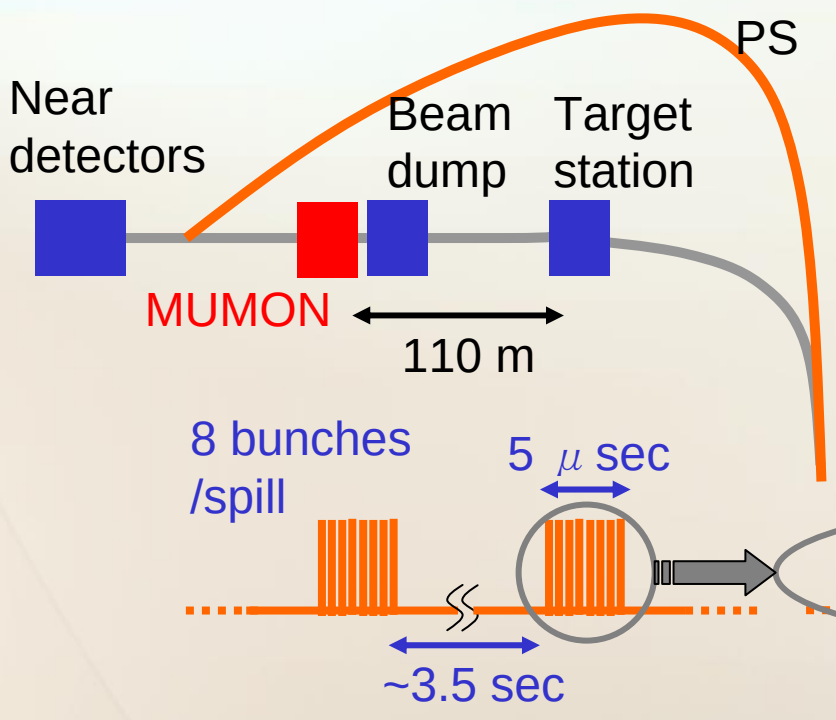
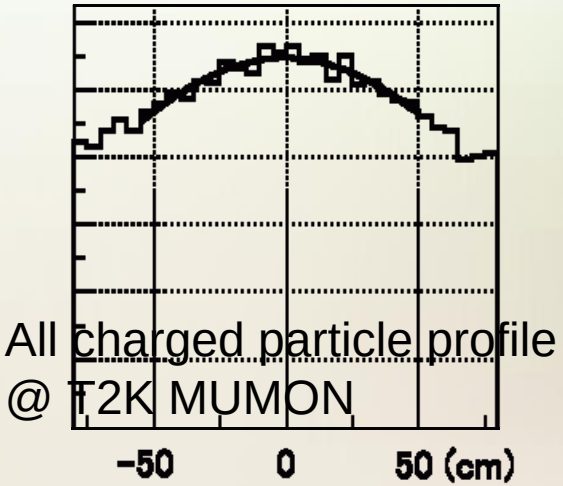
- Summary

T2K muon monitor (MUMON)

- **Monitor the secondary beam directions by measuring muon profiles on a bunch by bunch basis**
- **Cover 160 x 160 cm^2 area**
- **Direct ν beam in 1 mrad, corr. to 11 cm at MUMON**
  $\rightarrow$ Requirement for precision of profile center: 3 cm
- **Sensitive to the p targeting pos. and the horn magnet status**
- **Readout by FADC (65 MHz, 12 bit, $\pm$1 V)**

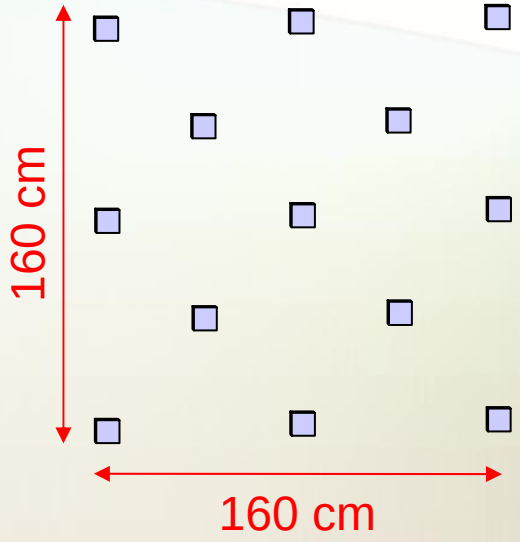




MUMON detectors

- **Two independent systems for redundancy**
  - **Array of semiconductor detectors**
  - **Array of ionization chambers**

Array of semiconductor detectors

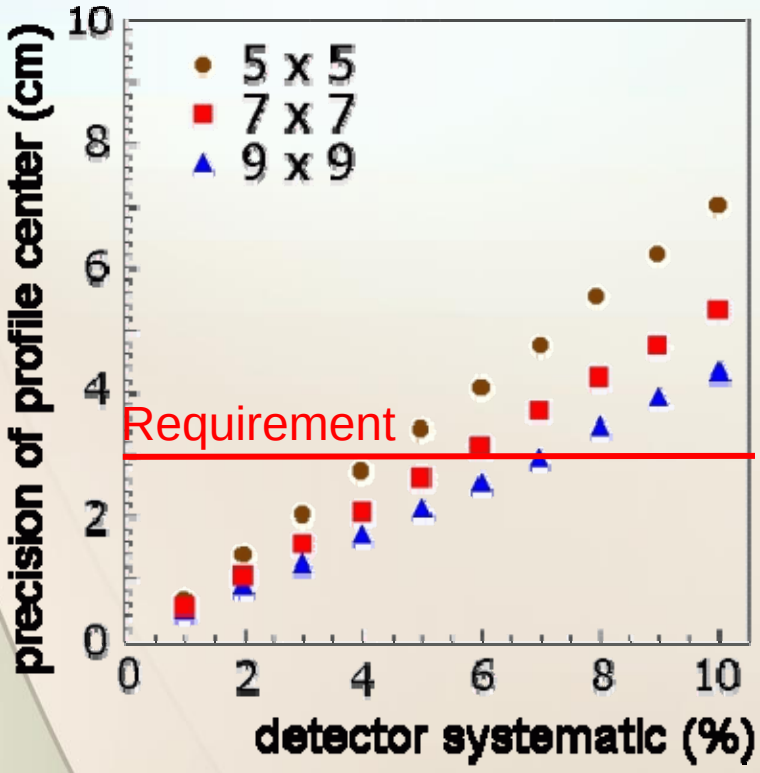


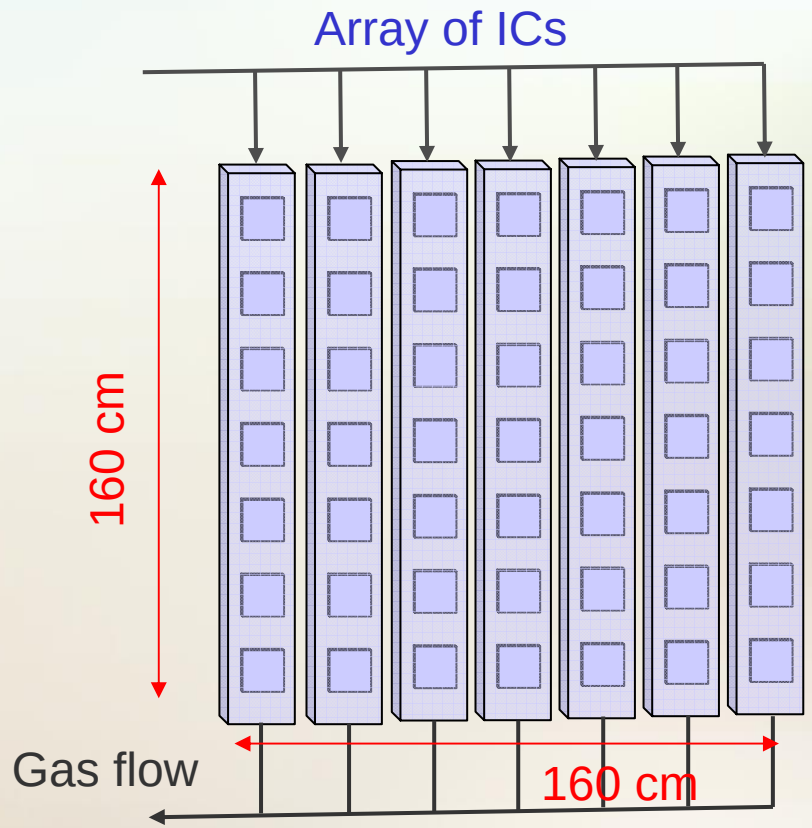
➢ **Semiconductor detectors**
  - **Silicon PIN photodiodes**
    - ◎ **Good response**
    - ▲ **Radiation damage**
      - **~1 x 10^8 muons/cm^2/spill**
      - **~10^7 neutrons/cm^2/spill**
  - **CVD diamond detectors**
    - ◎ **Tolerant of radiation**
    - ▲ **Unknown basic performance**
    - ▲ **Cost**

Is diamond an alternative to silicon?

MUMON detectors (cont'd)

- **Parallel plate ionization chambers (IC)**
  - **He gas (cover 10-100 % of T2K full intensity)**
  - **Ar gas in commissioning (cover 1-10 % of T2K full intensity)**
  - **Plate gap size?**
  - **Number of channels?**





Beam test w/ electron LINAC

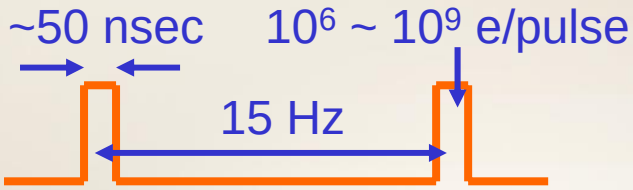
- **Measured items**
  - **CVD diamond detectors**
    - **Bias voltage scan**
    - **Linearity**
    - **Warm-up time**
    - **Stability**
  - **Ionization chambers**

    (two 3mm-gap and a 10 mm-gap both in He and Ar)
    - **Bias voltage scan**
    - **Linearity**

At the intensities in the expected T2K beam (Max. 1.6 x 10^7 μ /cm^2/bunch)

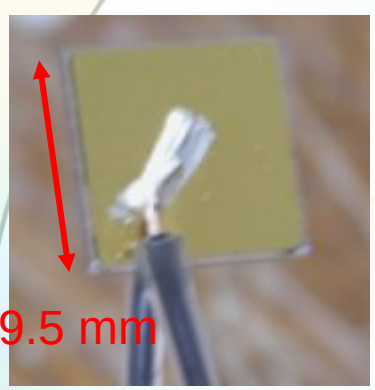
Electron LINAC @ Inst. for Chem. Res. Kyoto Univ.

- 100 MeV electron
- Intensity: 10^6 ~ 10^9 e/pulse
- Radius (σ): ~1 cm
- Pulse width: ~50 nsec
- Repetition: ~15 Hz



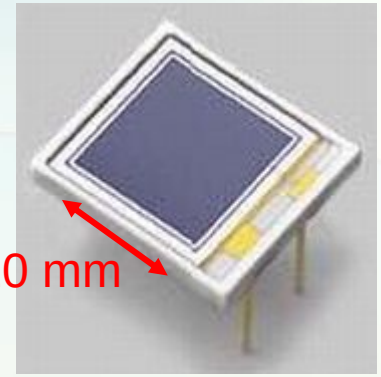
Setup for diamond test

CVD diamond detector

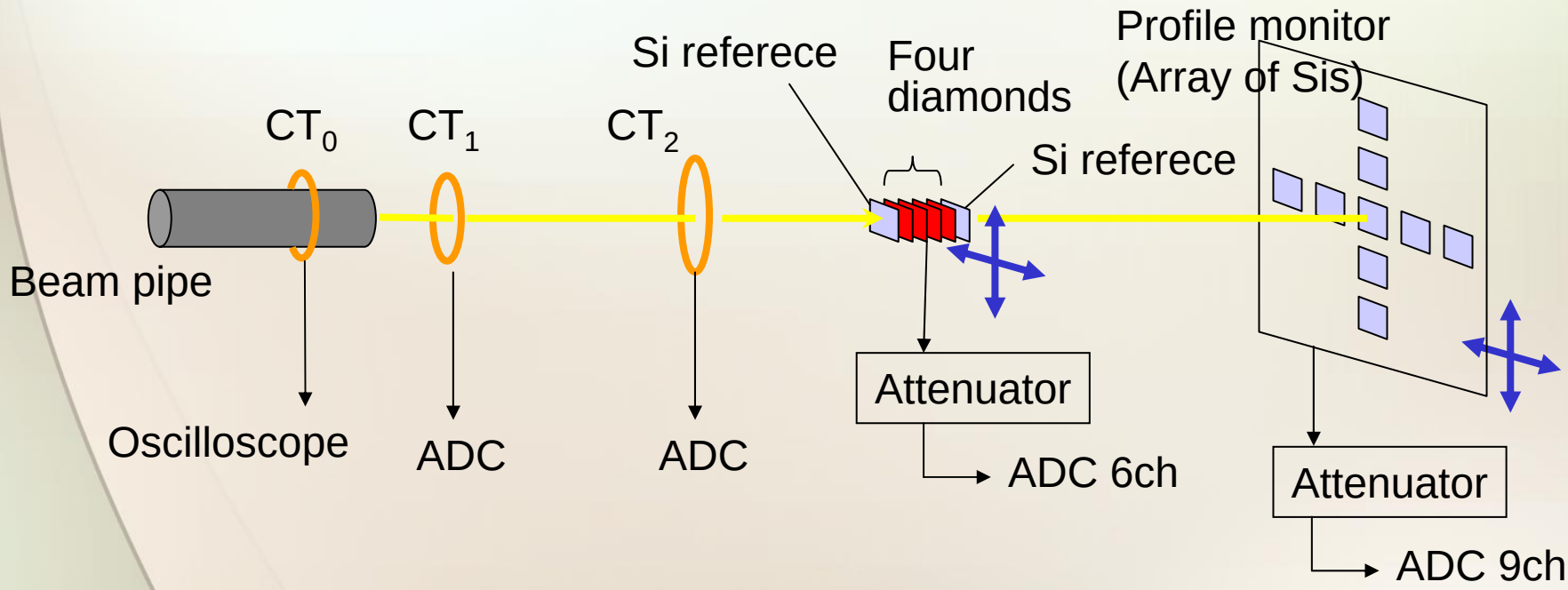


- **Developed by CERN RD42**
- **Active area: 9.5 x 9.5 mm²**
- **Thickness: 500 μ m**

Silicon PIN photodiode

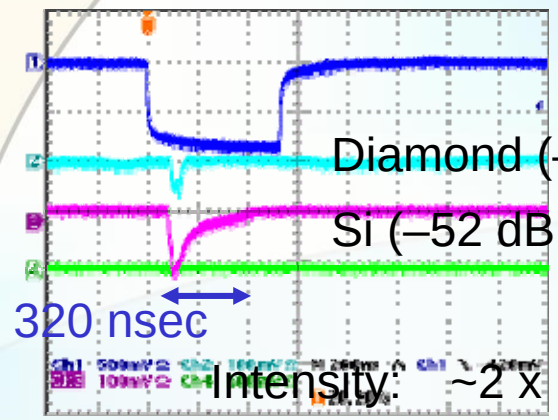


- **HAMAMATSU S3590-08**
- **Active area: 10 x 10 mm²**
- **Thickness: 300 μ m**



Bias voltage scan

Raw signal

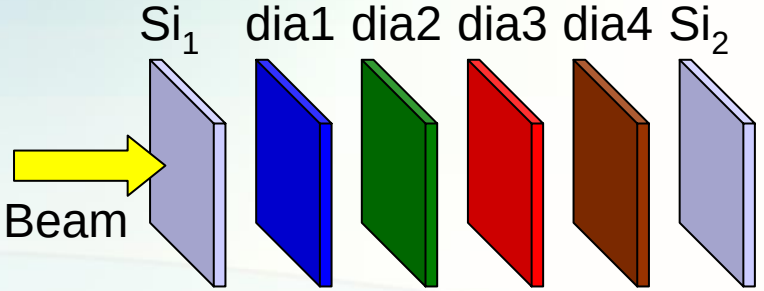


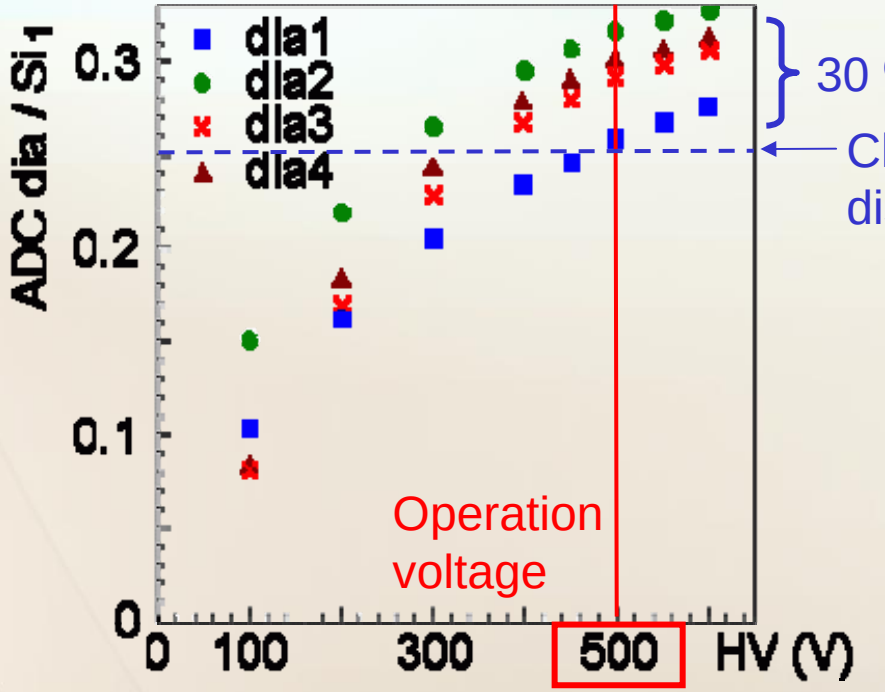
Diamond (–52 dB, 400 V)

Si (–52 dB, 80 V)

320 nsec

Intensity: ~2 x 10^7 e/cm^2/pulse



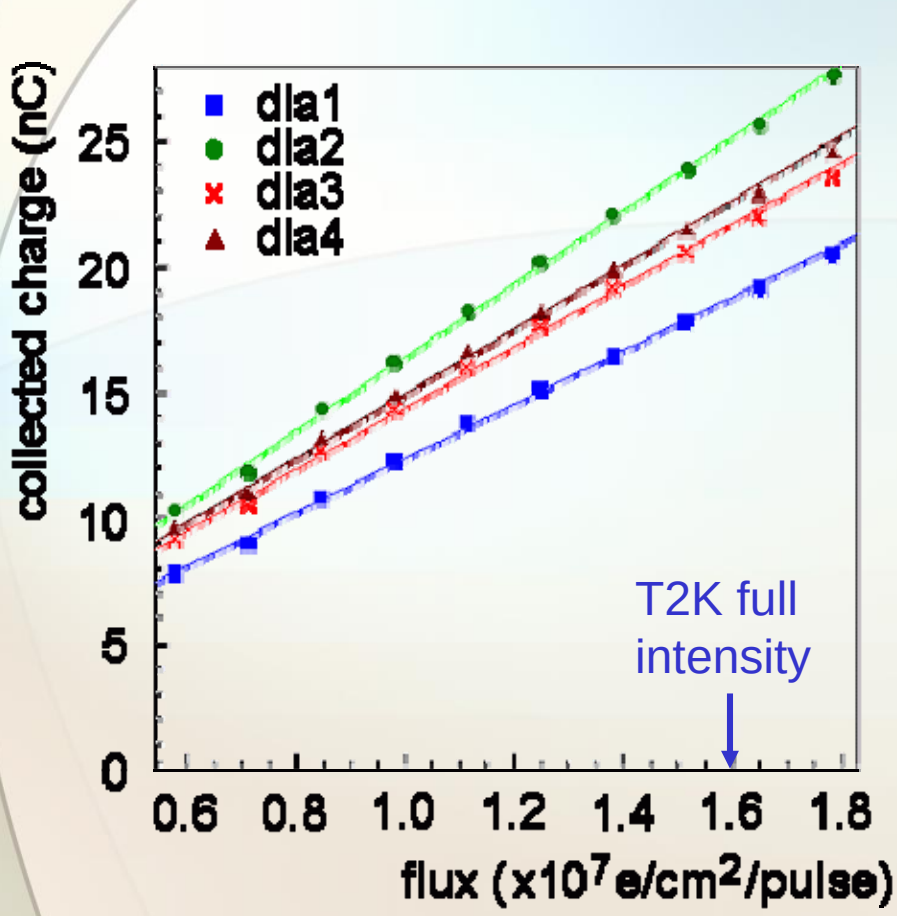


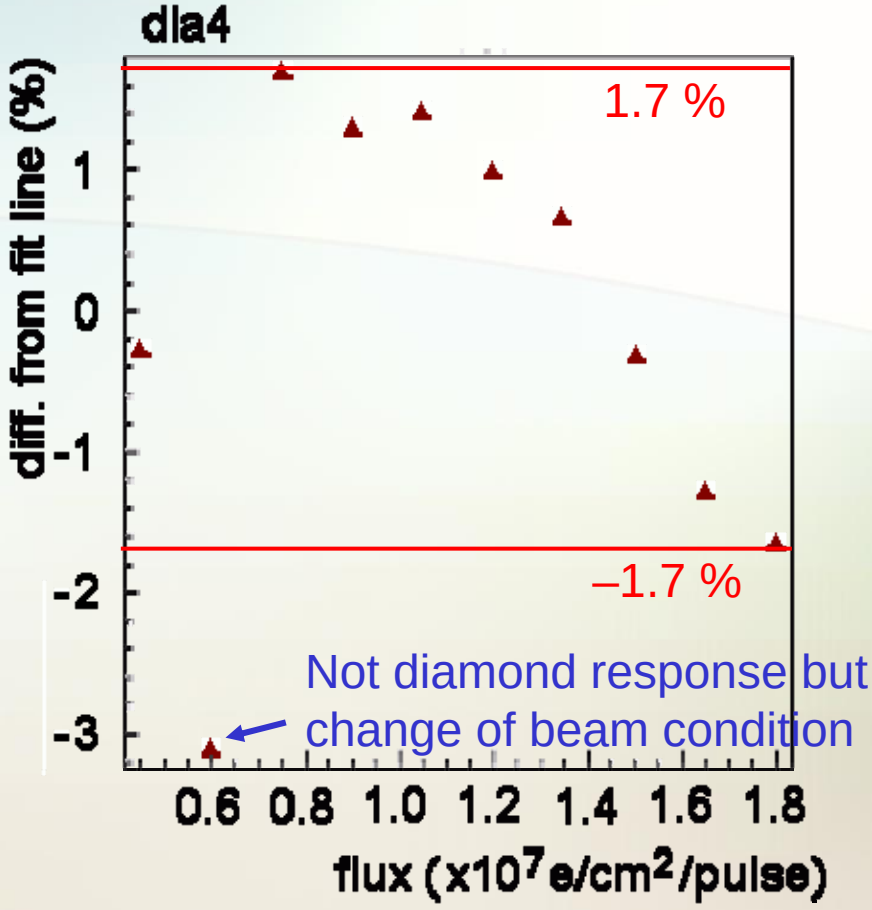
30 % diff.

Charge collection distance: 250 μ m

Bias voltage dependence is less than 0.1 %/V at 500 V.

Linearity



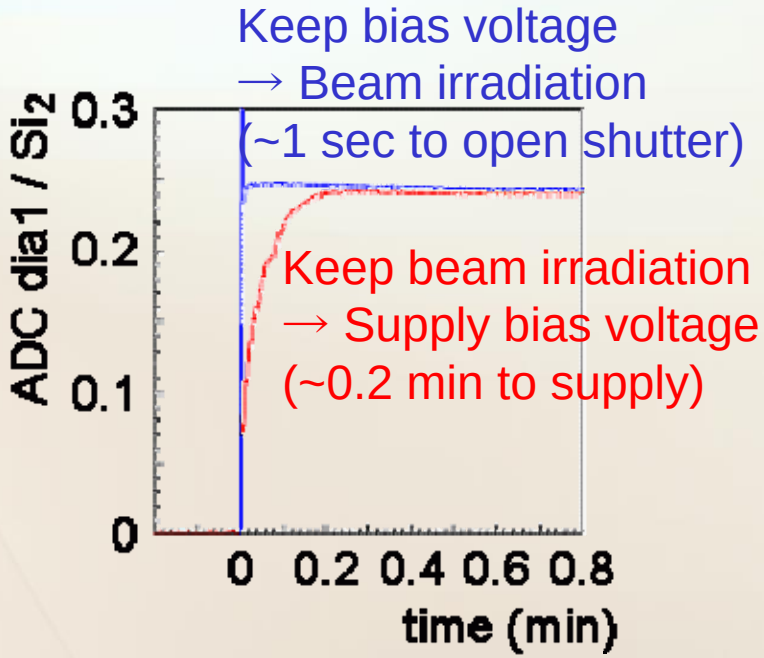


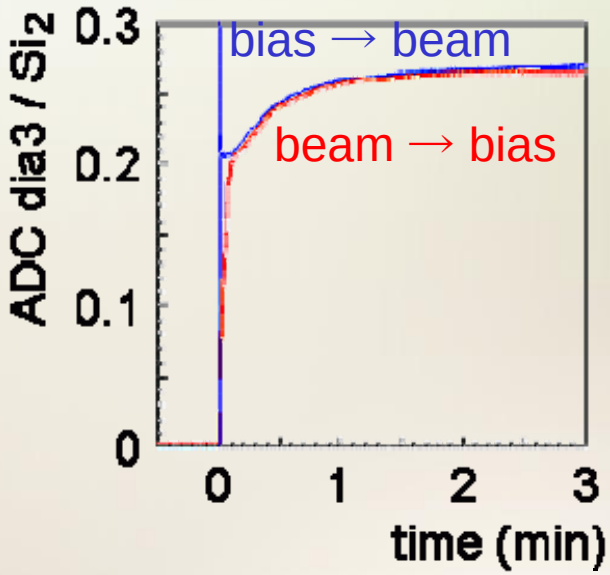
Responses of all diamonds are linear within 1.7 % difference.

Warm-up time

- **Two types of the responses**
  - **Warm-up time in the first irradiation**
    dia1,2 (left fig.): ~5 sec, dia3,4 (right fig.): ~3 min
  - **After 5 min interval of irradiation**
    dia1,2 : ~5 sec, dia3,4: ~20 sec

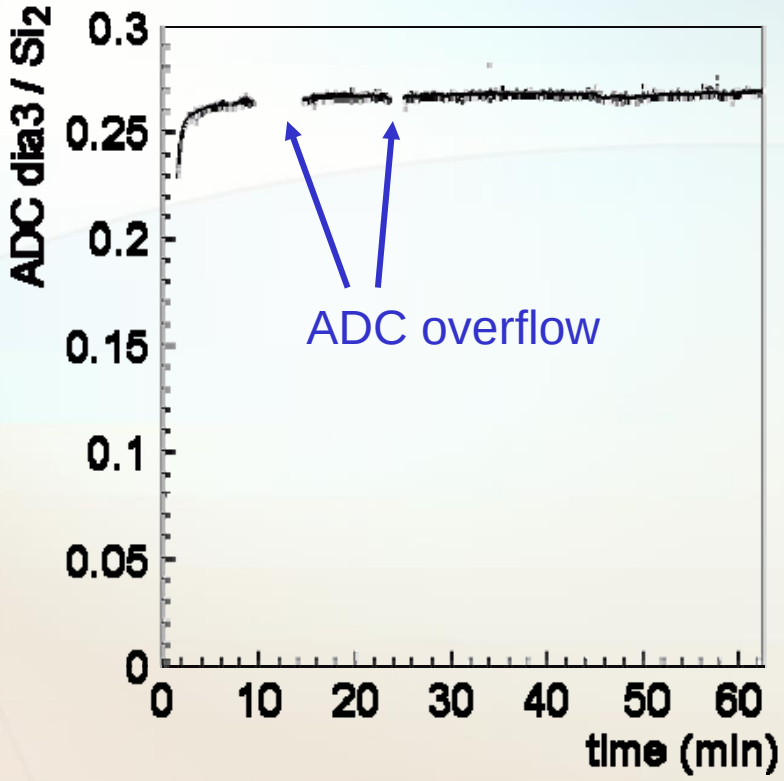
→ Need to check at 3.5 sec intervals (T2K spill intervals)

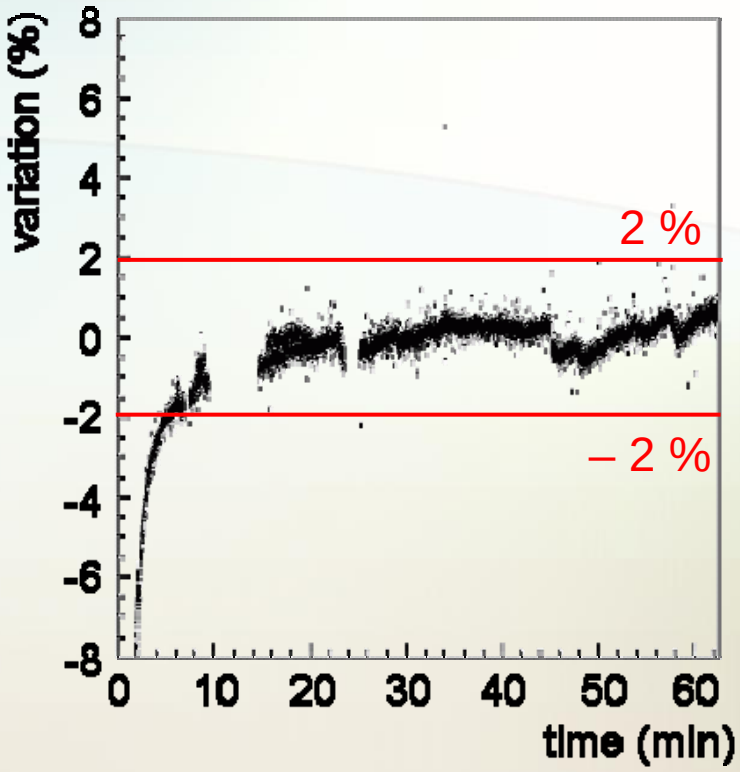




Stability

- **1 hour continuous operation**

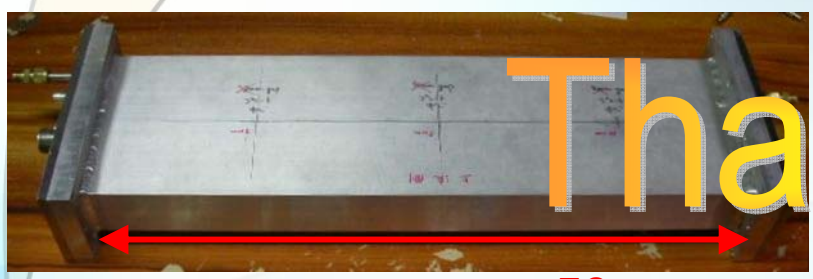




Signal responses of four diamonds are all stable within ±2 % variation after warm-up time of 3 min.

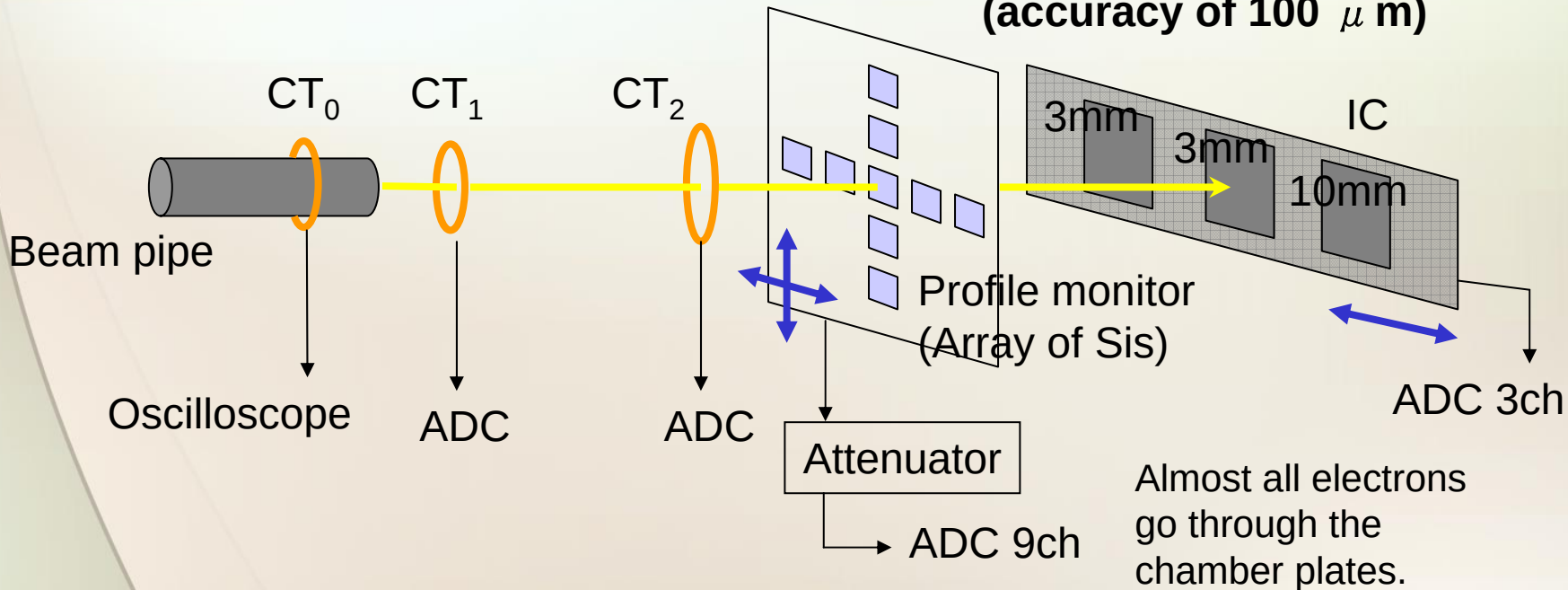
Setup for IC test

Ionization chamber prototype



Thank you!

- **Design of NuMI type**
- **The gas vol. tube contains 3 chambers (two 3mm-gap and a 10mm-gap chambers)**
- **Electrodes on G10 plates**
  - **75 x 75 mm^2 for signal**
  - **100 x 100 mm^2 for bias**
- **Ceramic spacer b/w plates (accuracy of 100 μ m)**

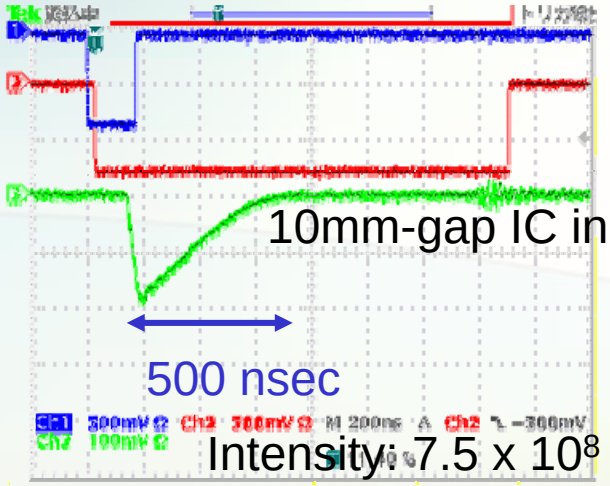


Almost all electrons go through the chamber plates.

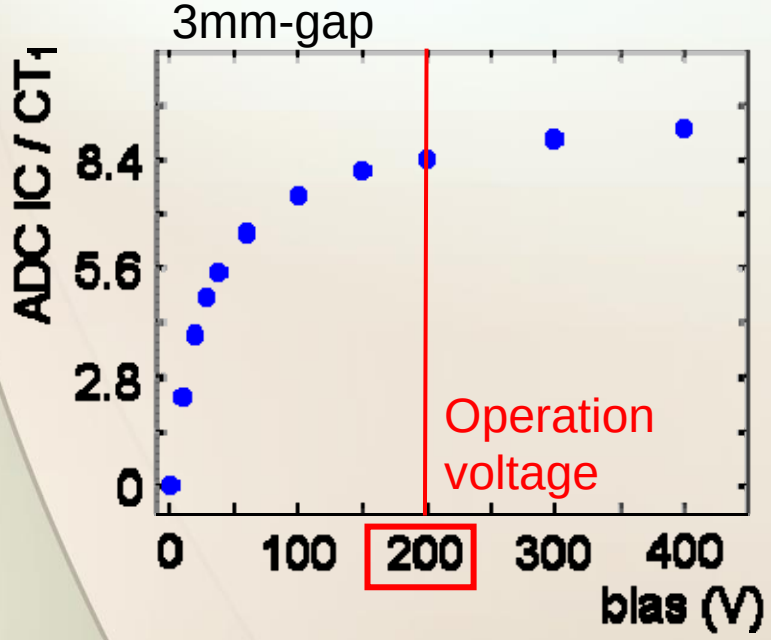
Bias voltage scan (He gas)

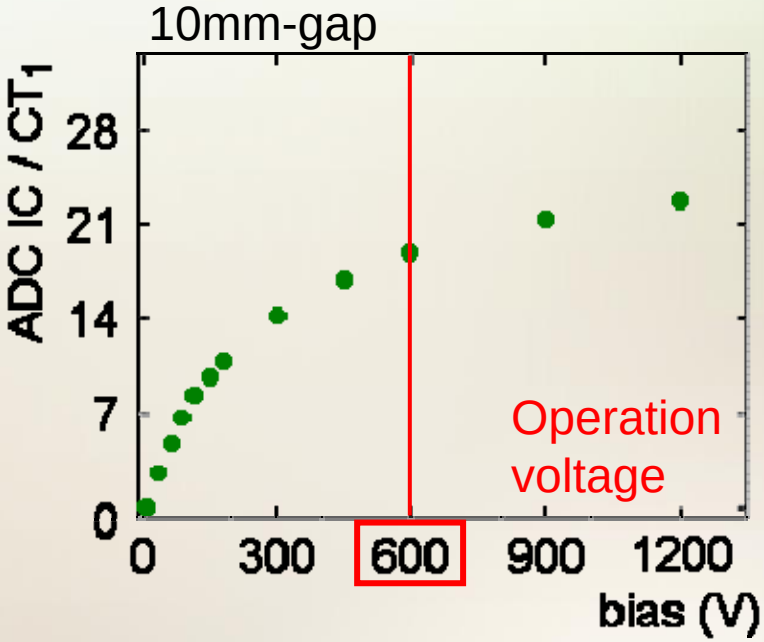
- **Scan from 0 to 400 (1200) V and in reverse order**
  - **Reproducibility: less than 2 % variation**

Raw signal

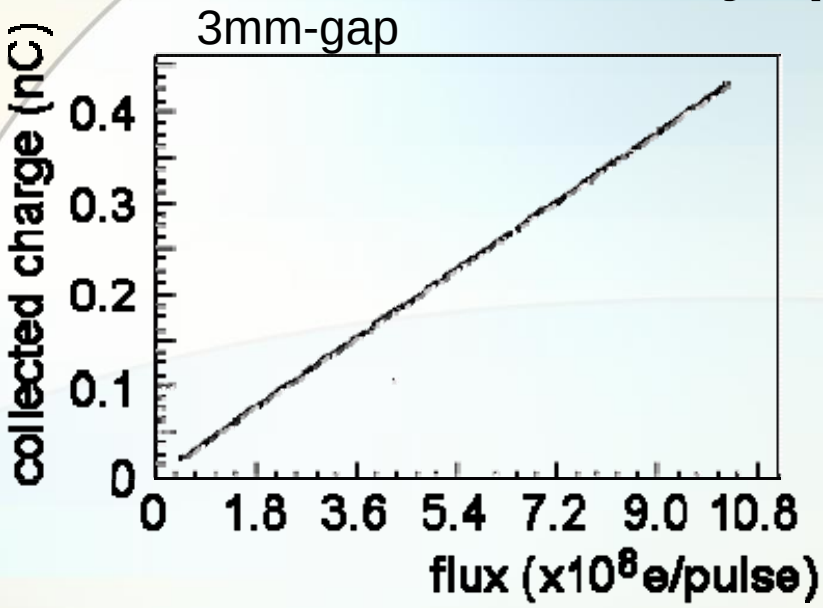


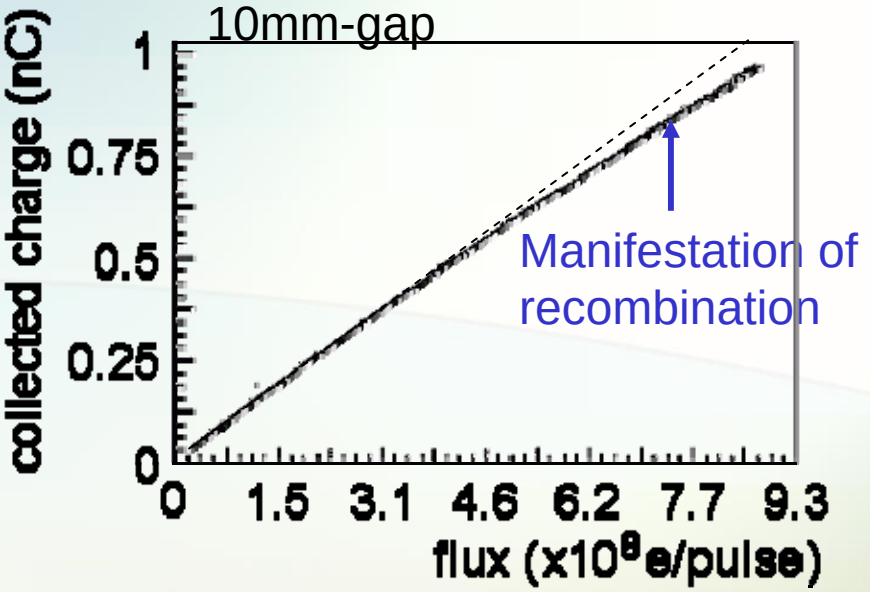
Intensity: 7.5 x 10^8 e/pulse

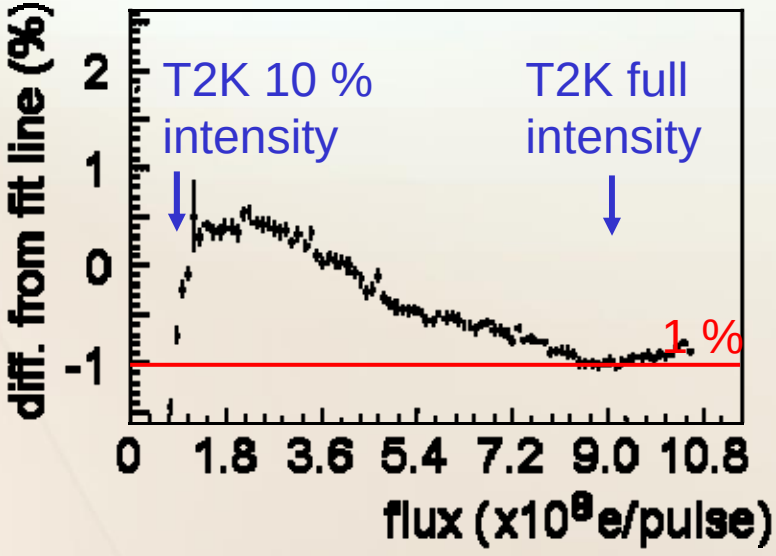


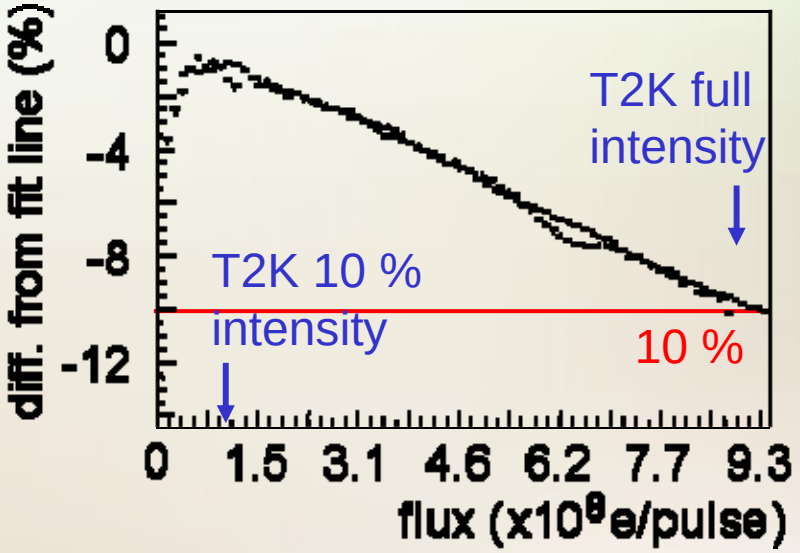


Linearity (He gas)







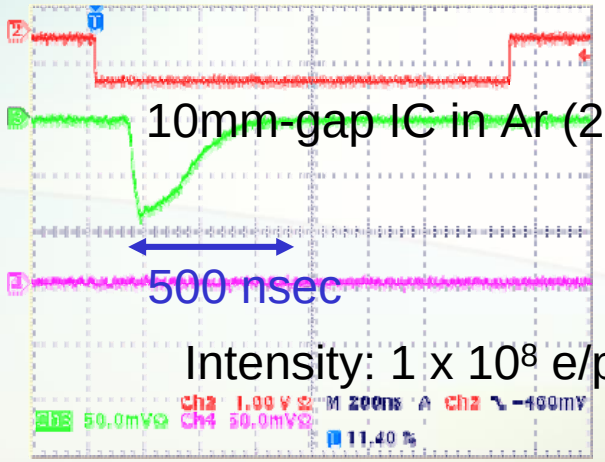


3mm-gap chamber has a good linearity at 10~100 % of T2K full intensity.

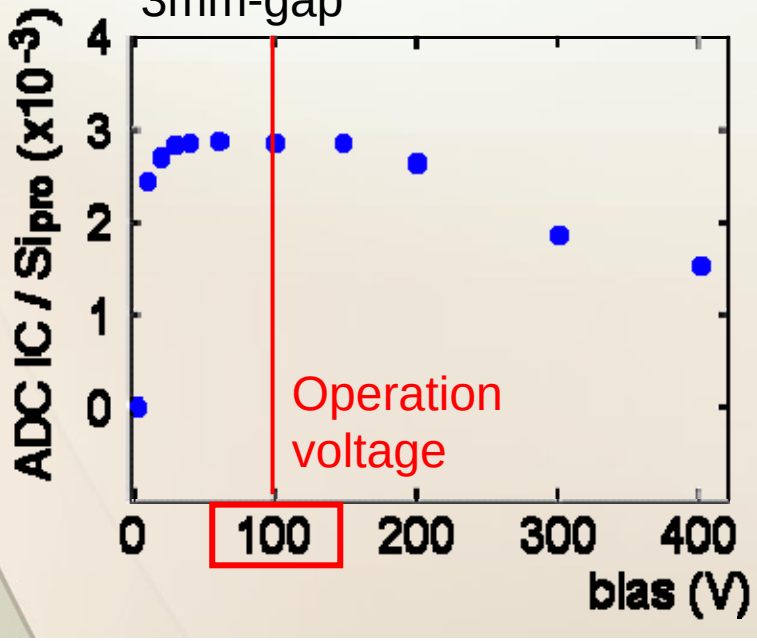
Bias voltage scan (Ar gas)

- **At the intensities in the T2K commissioning beam (~1 % of the T2K full intensity beam)**
- **Scan from 0 to 400 (1200) V and in reverse order**
  - **Reproducibility: less than 1 % variation**
- **Earlier depletion than in the case of He gas**

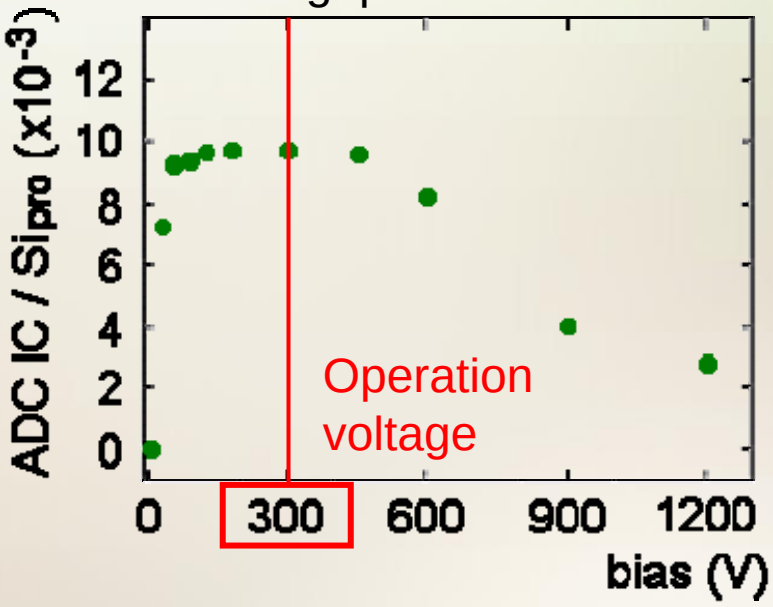
Raw signal



3mm-gap

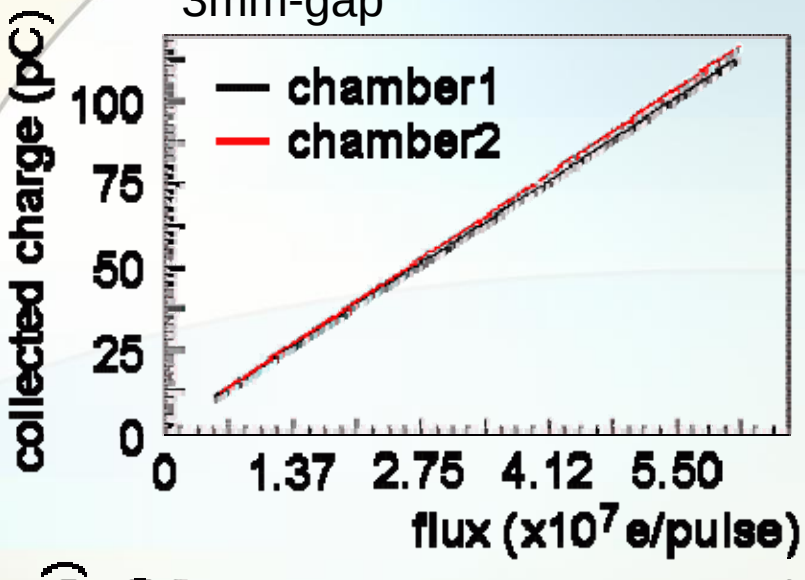


10mm-gap

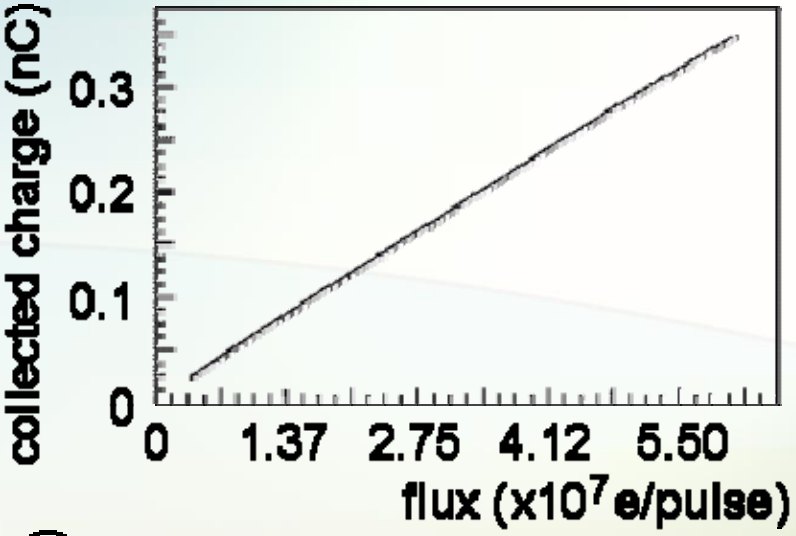


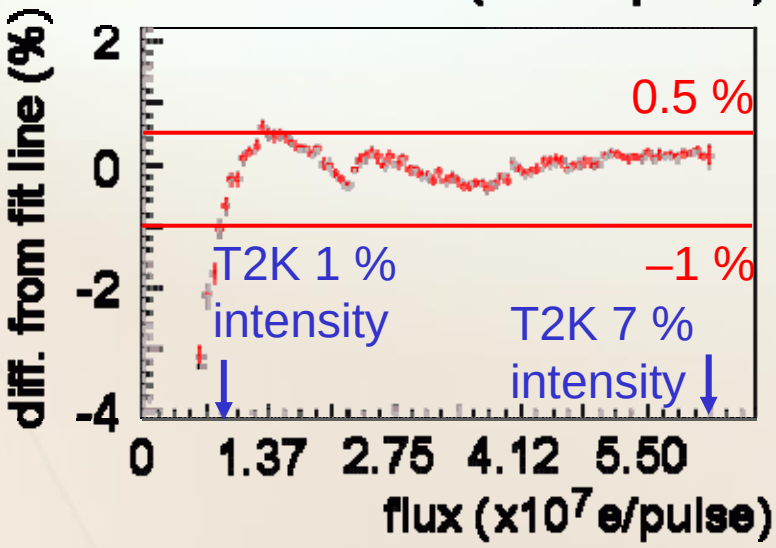
Linearity (Ar gas)

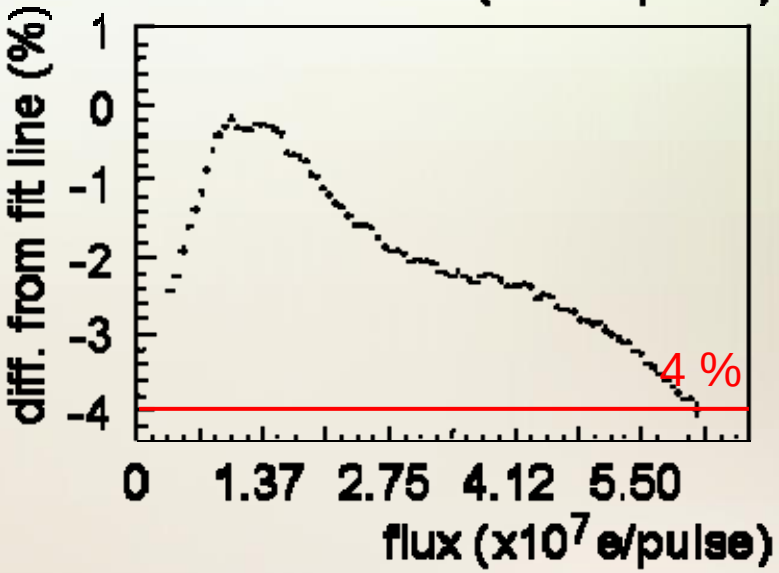
3mm-gap



10mm-gap







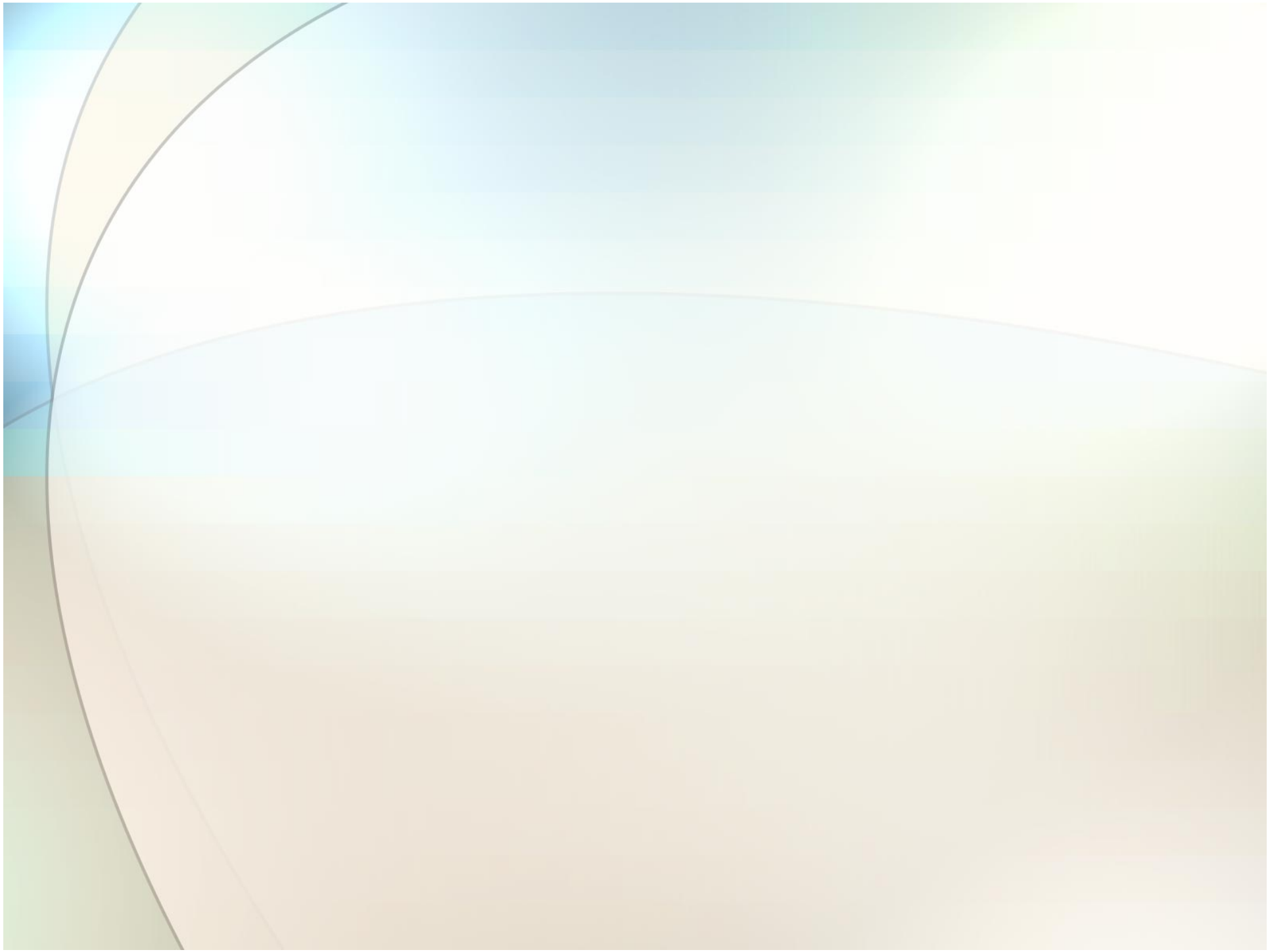
3mm-gap chamber has a good linearity at 1~7 % of T2K full intensity.

Summary

- **CVD diamond detectors**
  - **Linearity and stability are as good as those of silicon**
  - **Need further studies**
    - **Warm-up time at the T2K spill intervals, etc.**
- **Ionization chamber**
  - **Both in He and Ar, 3mm-gap chamber is better than 10mm-gap**
    - **Good reproducibility (< 2 %)**
    - **Linear response in 1~7 % (Ar) and 10~100 % (He) of T2K full intensity**
    - **Diff. b/ two chambers is small (1 % in He, 3 % in Ar)**

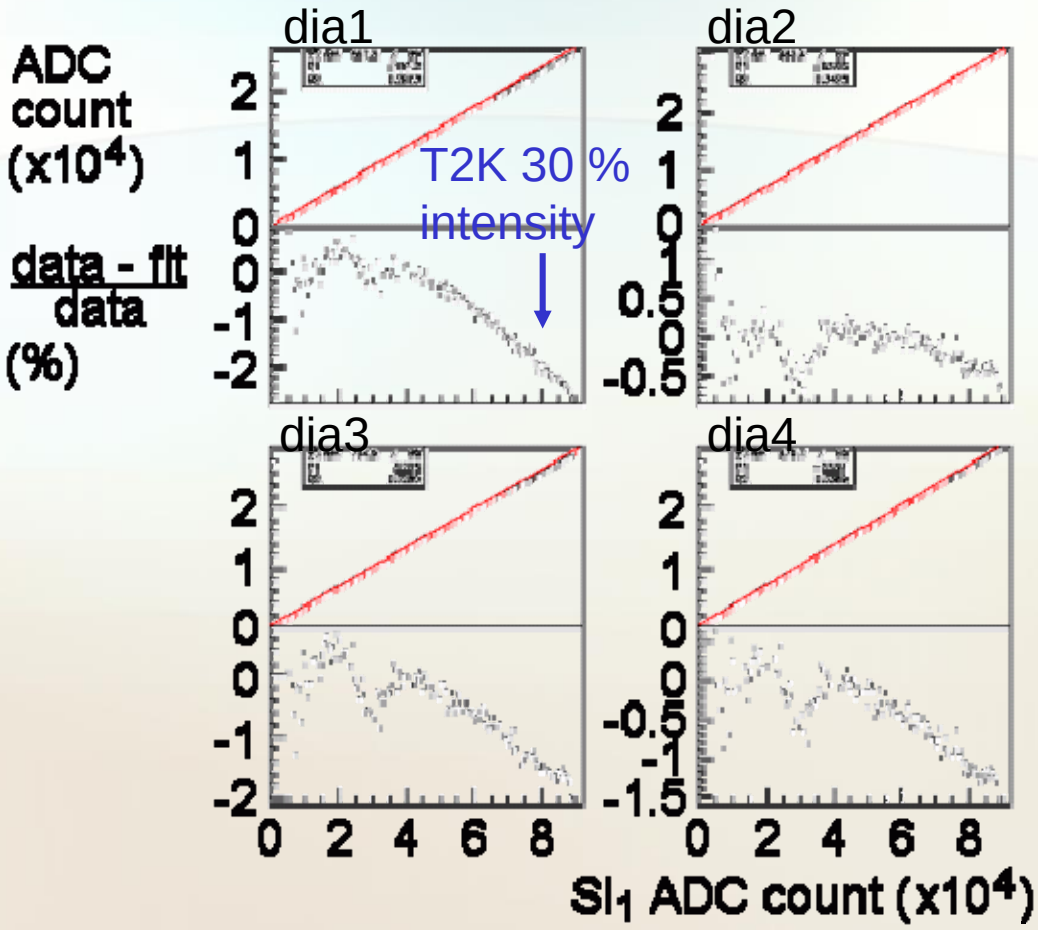
  → Use 3mm-gap chamber

  Fix the number of channels at 49 (7 x 7)
  - **Next step**
    - **Produce real chambers w/ ceramic plates and test them**
- **MUMON installation starts in Dec. 2008**

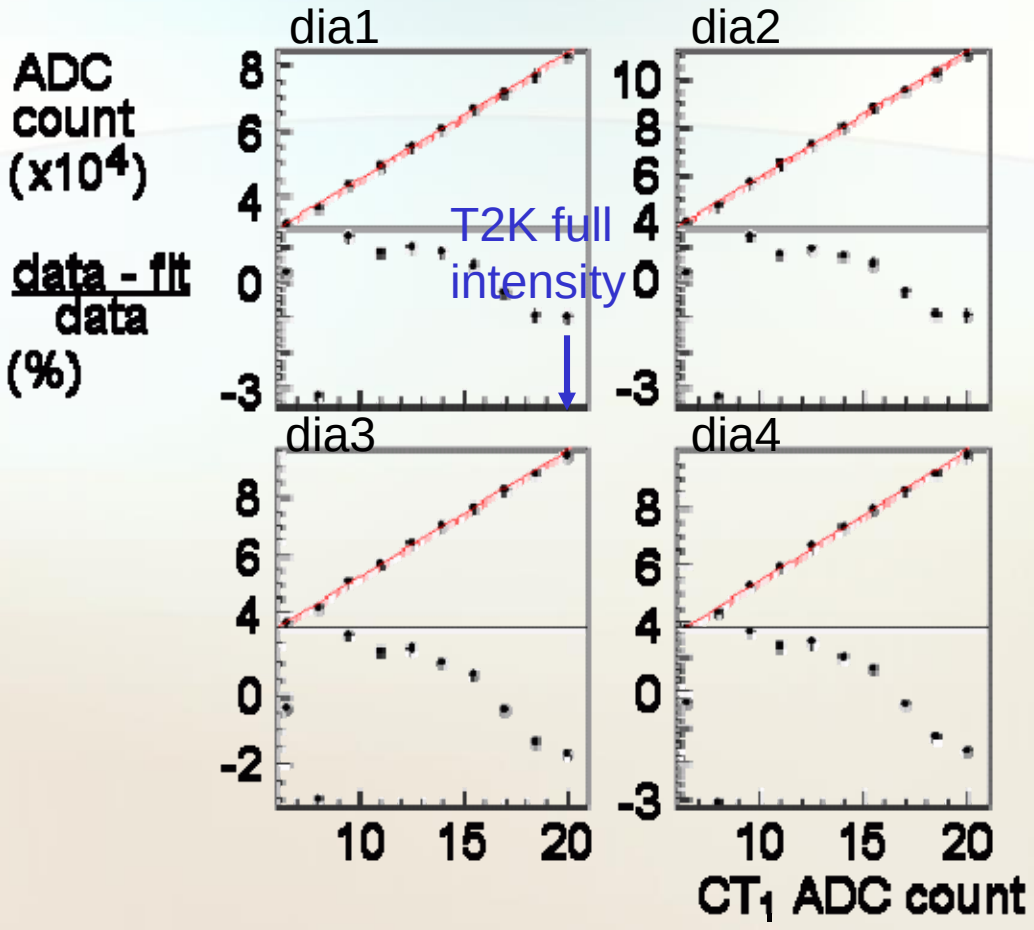


Supplement

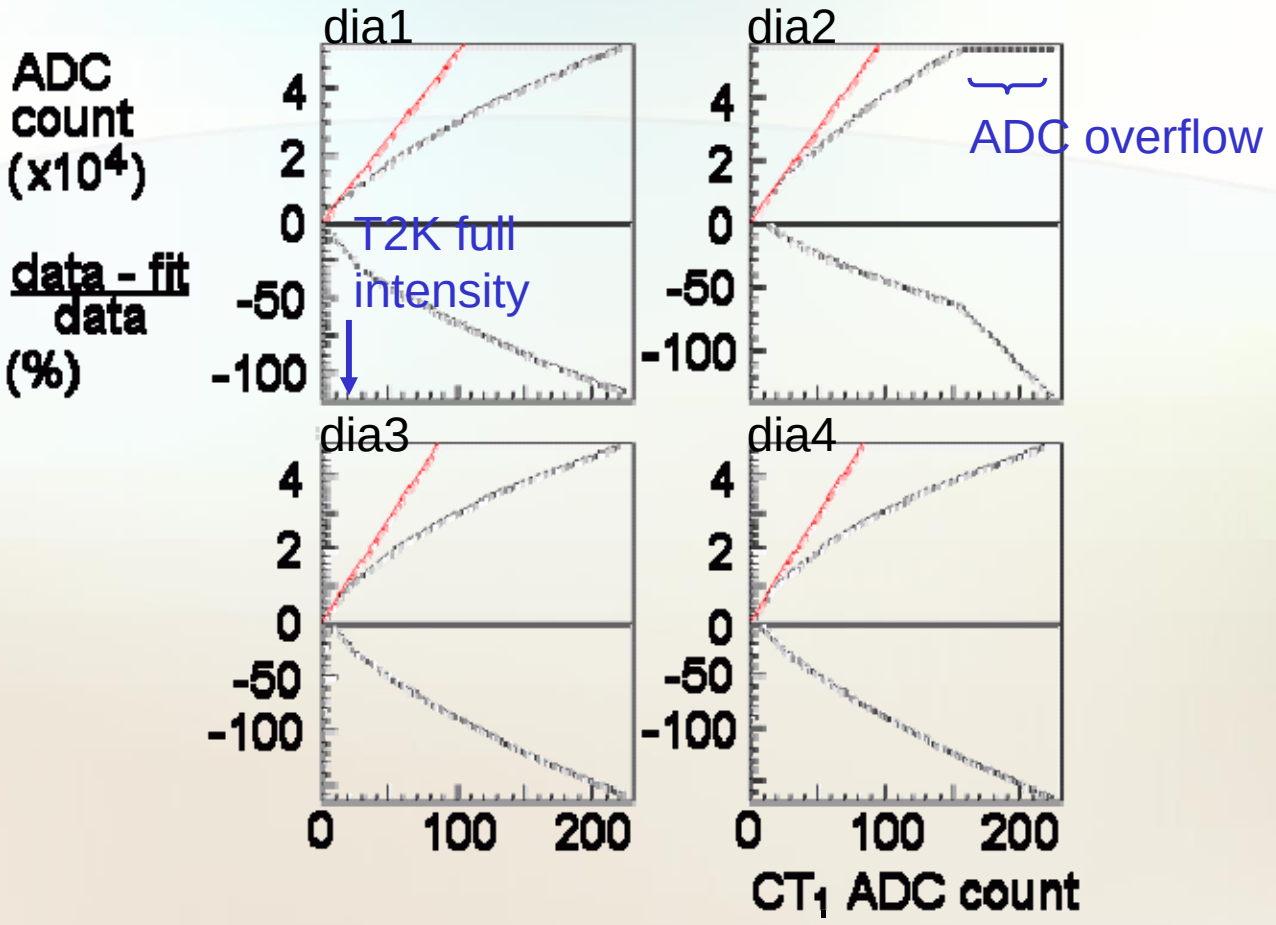
Linearity of diamonds at low intensities



Linearity of diamonds at middle intensities

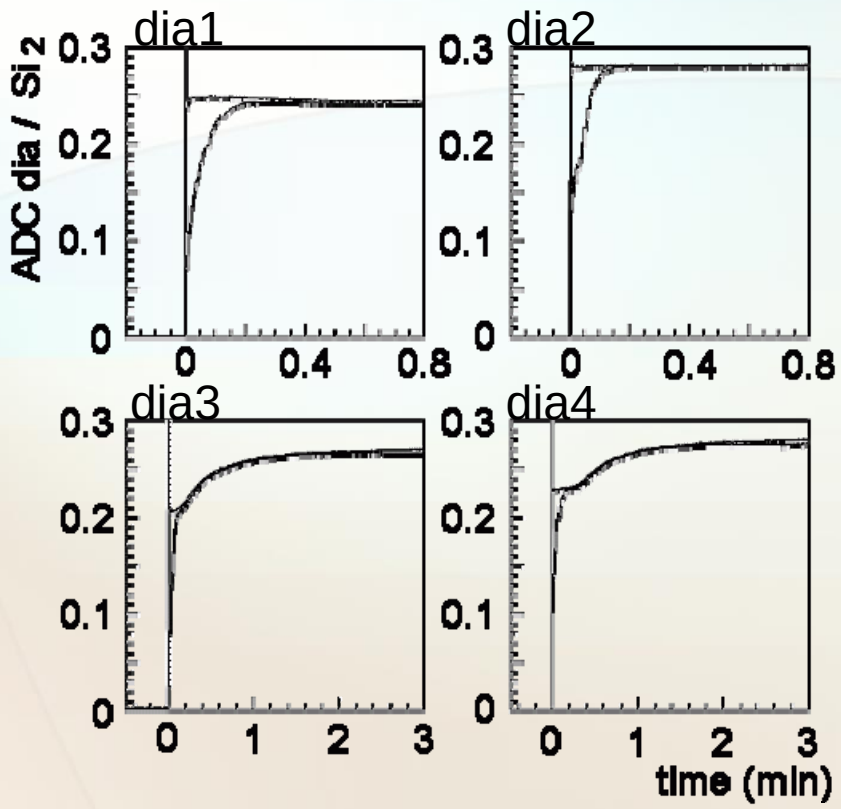


Linearity of diamonds at high intensities

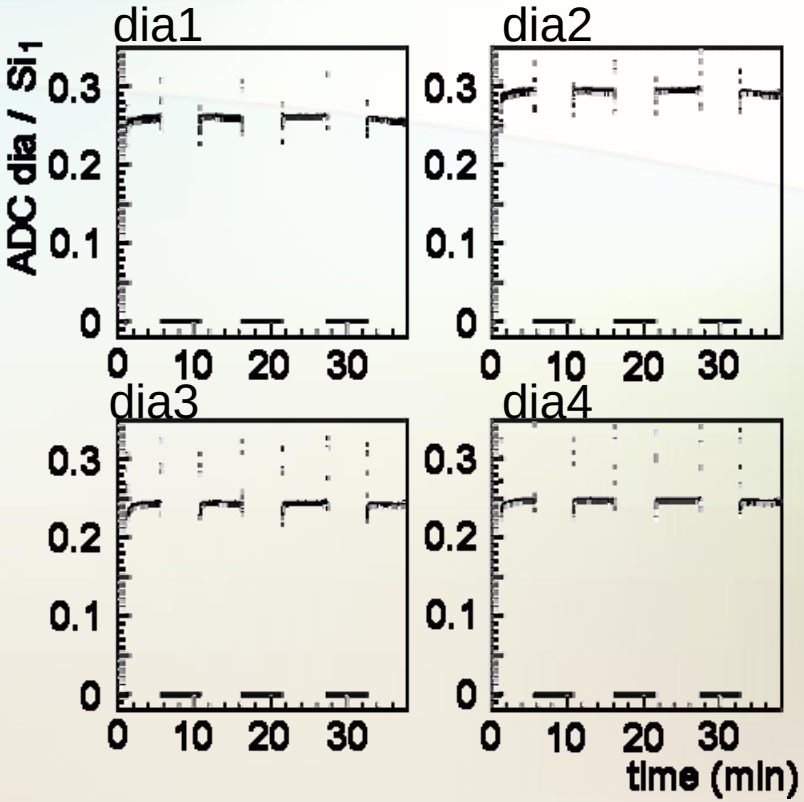


Warm-up time of diamonds

In the first irradiation



With intervals



Stability of diamonds