The **single-electron experiment**

in the ESRF Storage Ring &

future developments to improve bunch pollution measurements

on behalf of the
Diagnostics Group,
Accelerator Control Unit,
ID18 Beamline,
Beam Dynamic group and
Beam Operation group

Outline

1) A few figures about **current** and **electrons**
2) **Single-electron injection**
3) The **visible-light set-up** and lab
4) **Single-electron measurements**
5) **First application**
6) Conclusions

1) A few figures about current and electrons

Current = charge / time

- Time SR (EBS) = 2.8 µs
- Time SY (Booster) = 1 µs

min

max

Smallest current = $5.7 \cdot 10^{-14}$ A ➡ **1 electron**

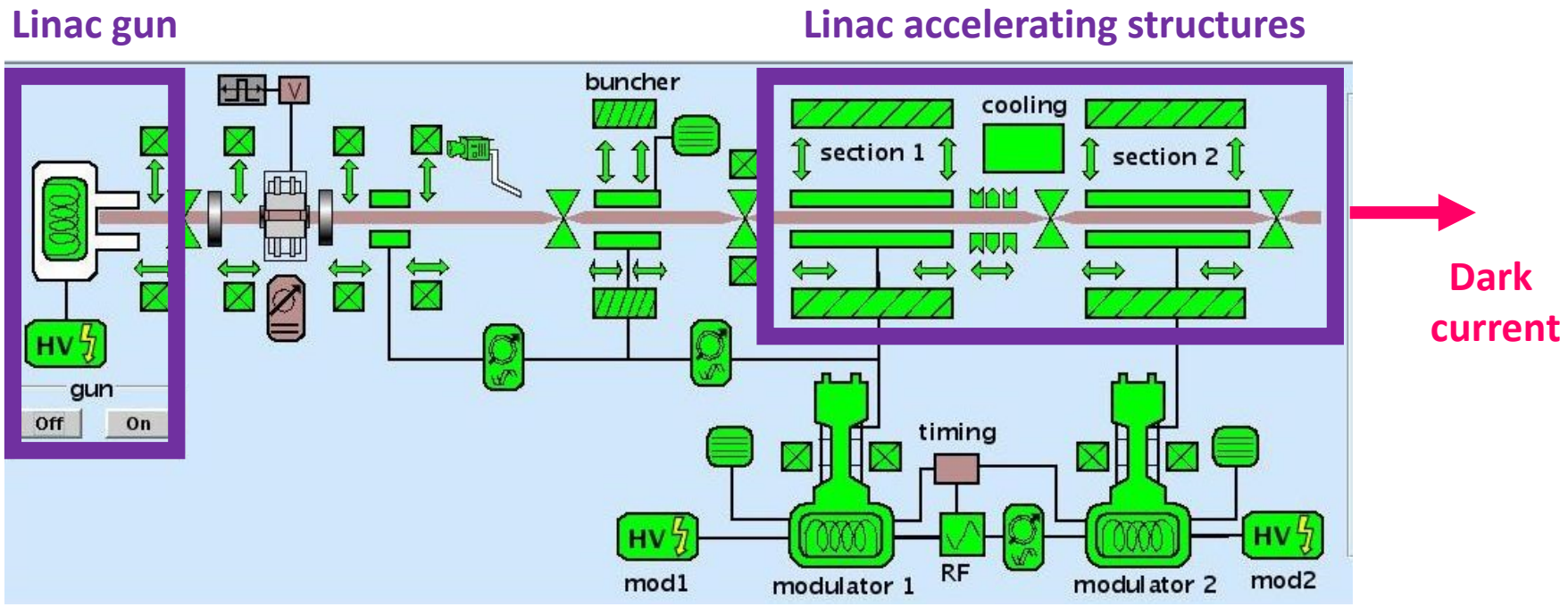
Dark current shot (Linac gun off) = $5.7 \cdot 10^{-13}$ to $5.7 \cdot 10^{-12}$ A ➡ 10 to 100 electrons

Injection shot (Linac gun on) = 1 Ma ➡ $6.3 \cdot 10^{9}$ electrons

Standard beam = **200 mA** ➡ $3.5 \cdot 10^{12}$ electrons

2) Single-electron injection

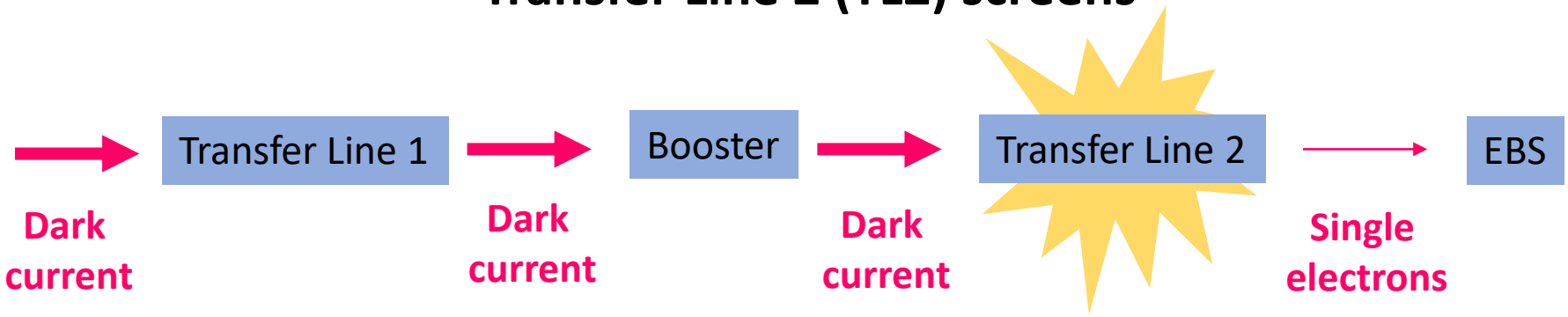
Linac injection system

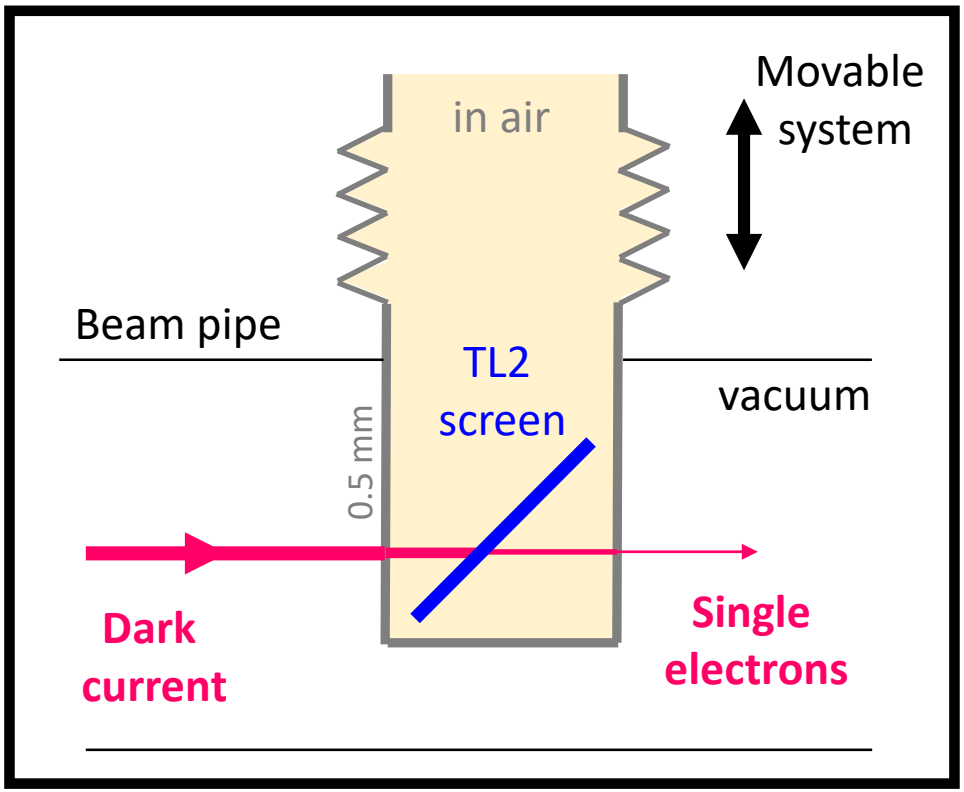


With **Linac gun off**, the **dark current** is only produced in **the Linac accelerating structures** [2 x 100 MeV]

2) Single-electron injection

Transfer Line 2 (TL2) screens





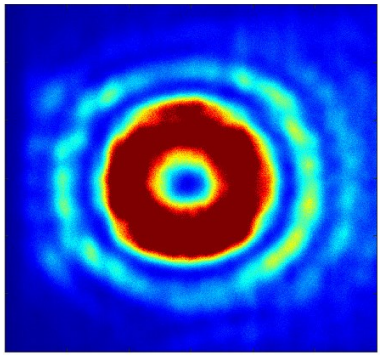
Insertion of the **interceptive Screens in the TL-2** (up to 4 screens in series): our electron attenuators

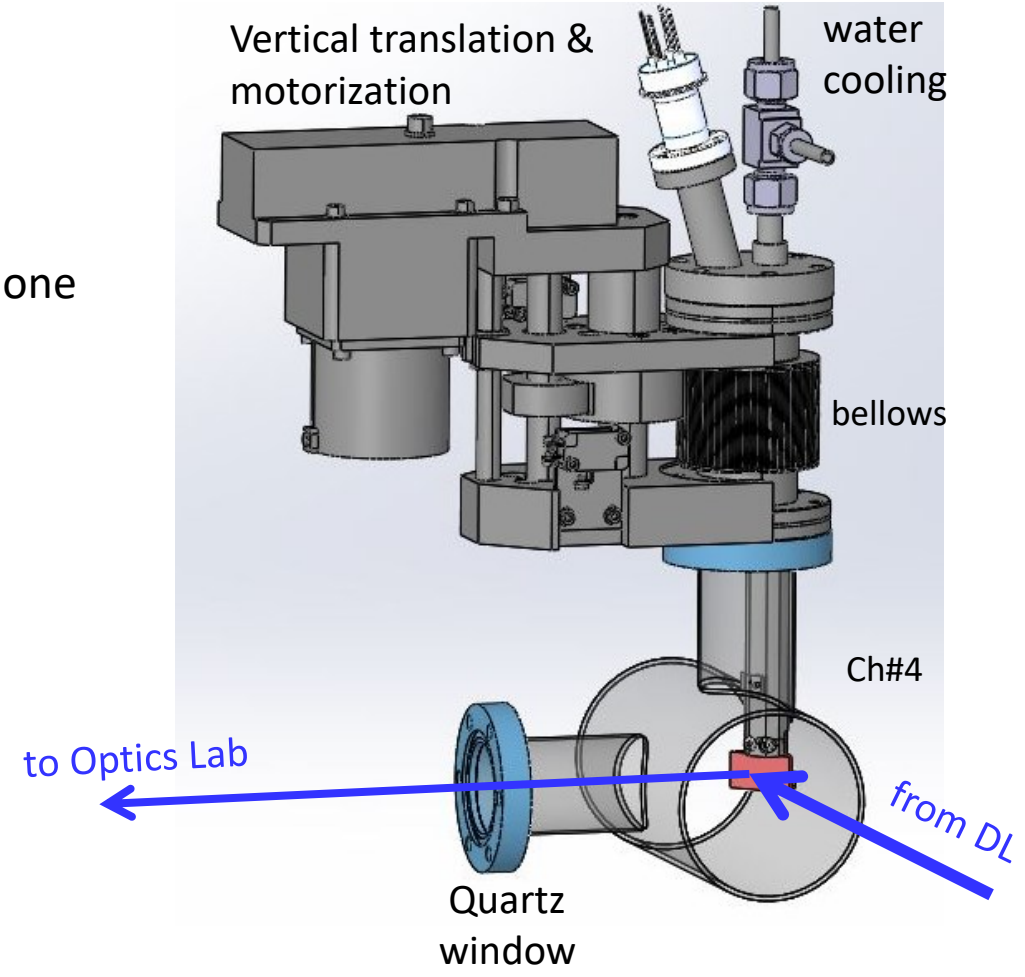
By drastically reducing the Injector current to a probability of **1 electron out of a few hundred injection shots**

3) The visible-light lab

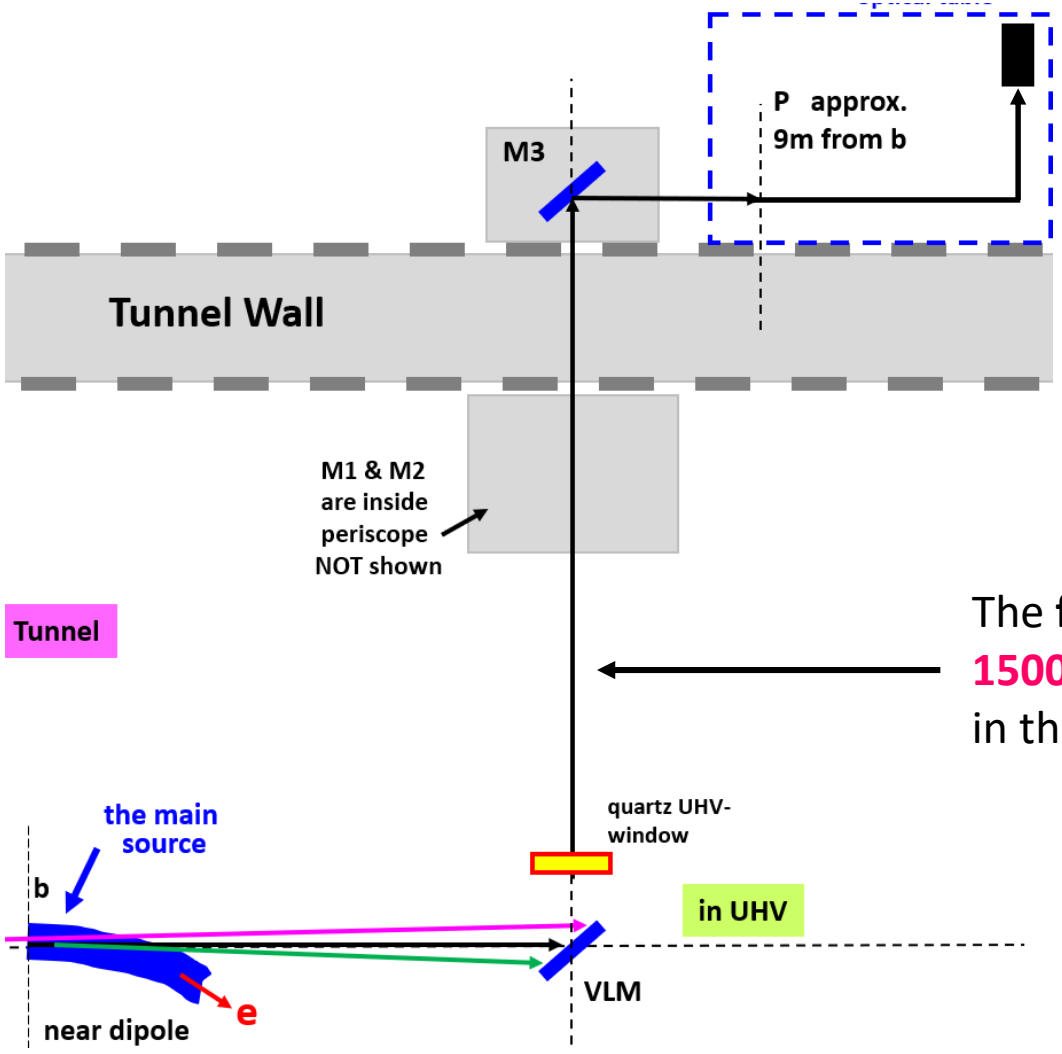
The ASD-visible light optics lab:

- Light has been fully characterized
- Streak Camera measurements been done





3) The visible-light set-up

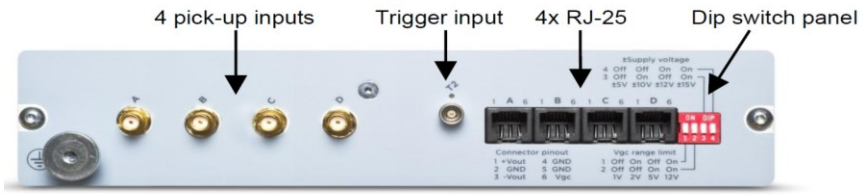


The light is focused on a cheap PMT that is controlled and measured by BLM electronics.

The **flux** is calculated at about
1500 photons/sec per electron stored
in the 400-700nm bandwidth of our PMT

3) The PMT and BLM electronics

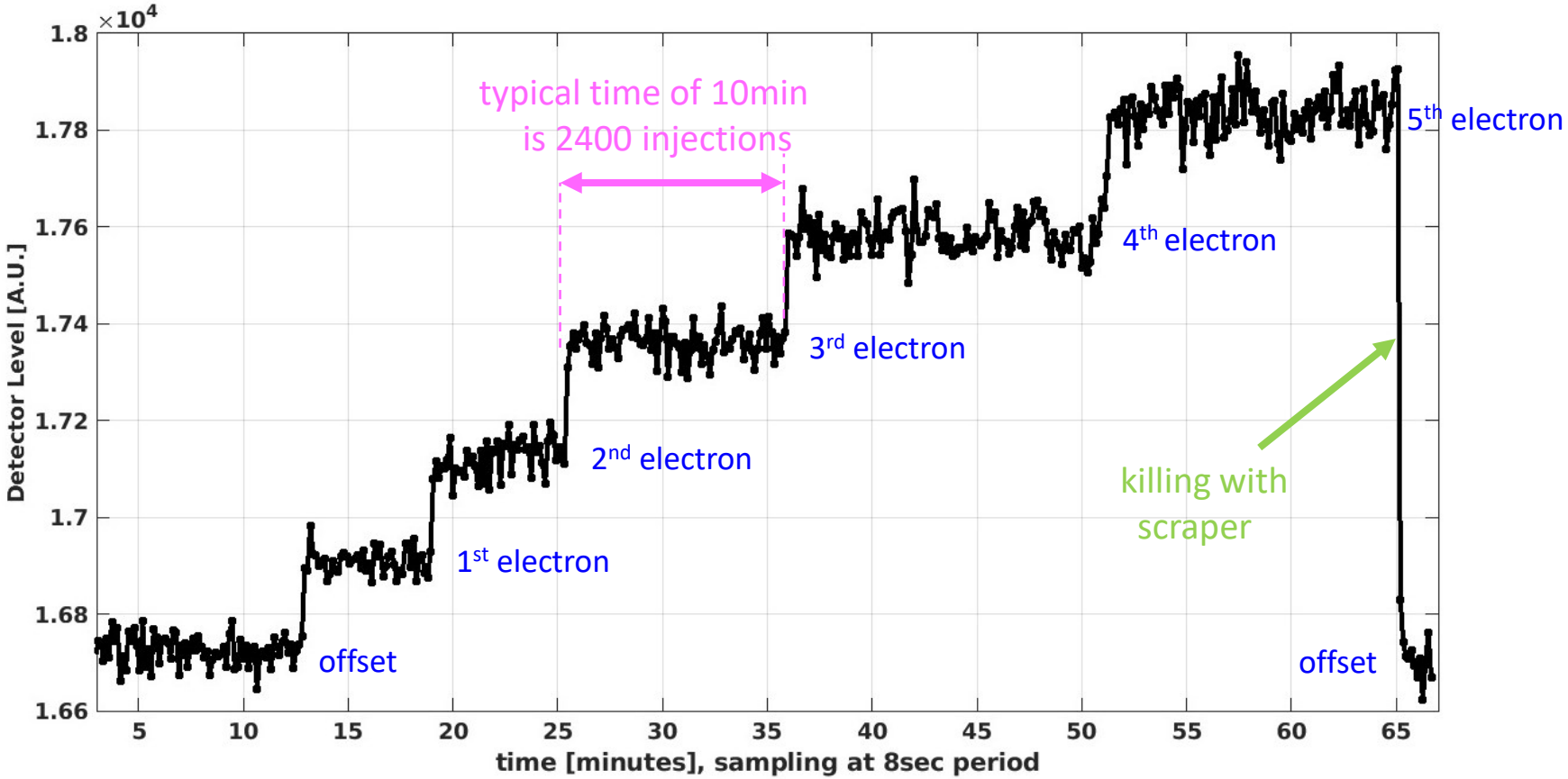
- A cheap **Photomultiplier Tube (PMT)** from Hamamatsu (what we use for our Beam Loss Detectors)
- Connected to the **Beam Loss Monitor (BLM)** from I-Tech



- Controlled by **TANGO application**
- Measurements performed in **integration mode** (1MΩ impedance & high gain)

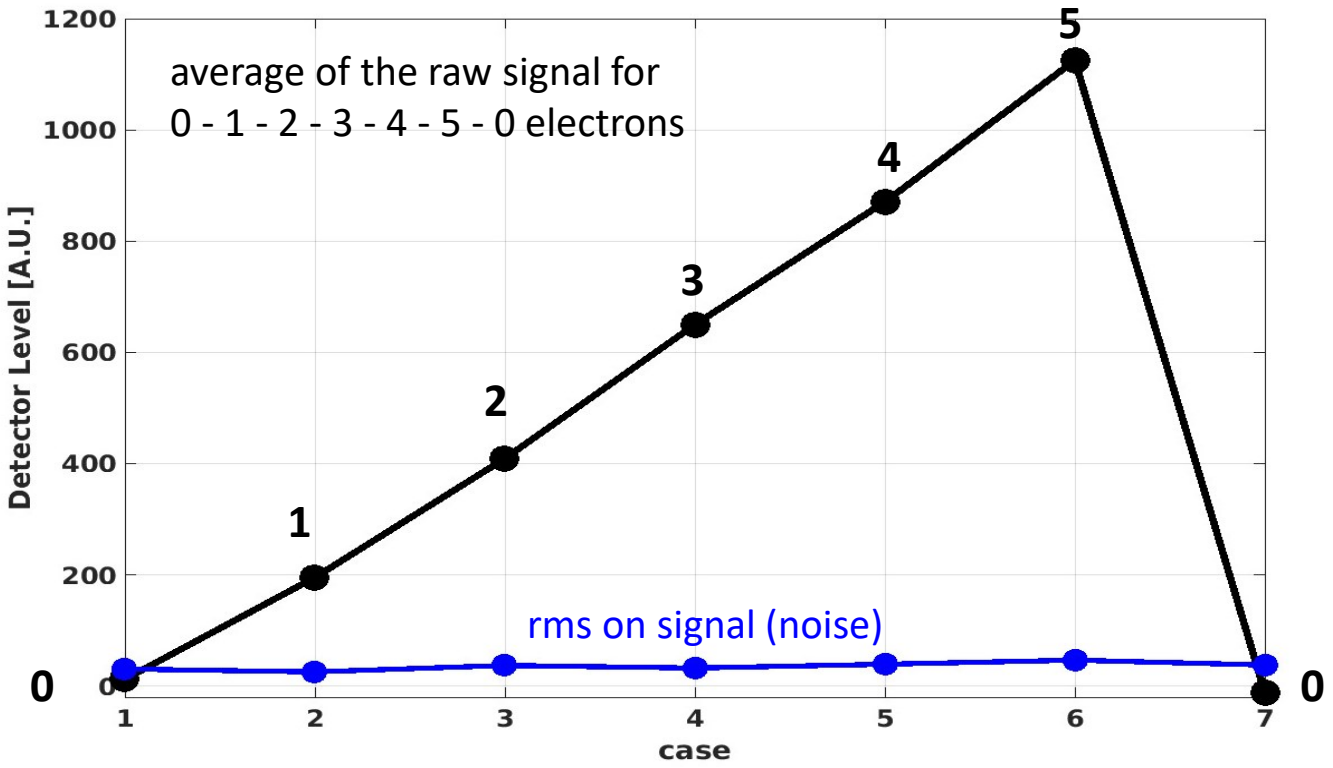
4) Single-electron measurements

- 1-2-3-4-5 electrons in about one hour
- Sampling time = 8 seconds



4) Single-electron measurements

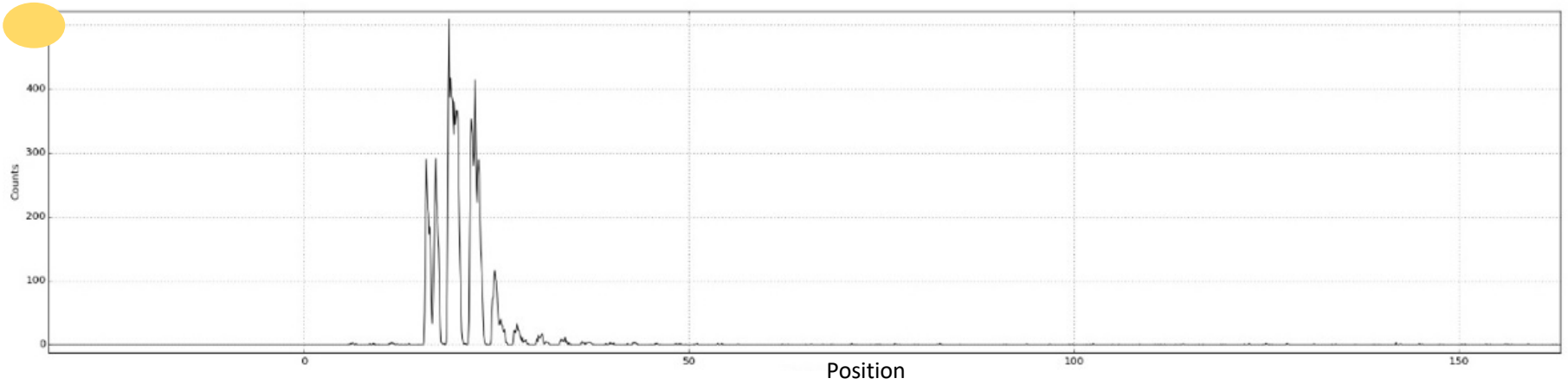
- signal-to-noise ratio is just > 6, for 8-second integration time
- a **higher performance PMT can have less noise** → we would **reduce the measurement time**



5) First application

Machine Development Time (MDT) with ID18 users to verify the bunch purity (7th March 2022)

- **Before optimization ➡ bunch impurities**

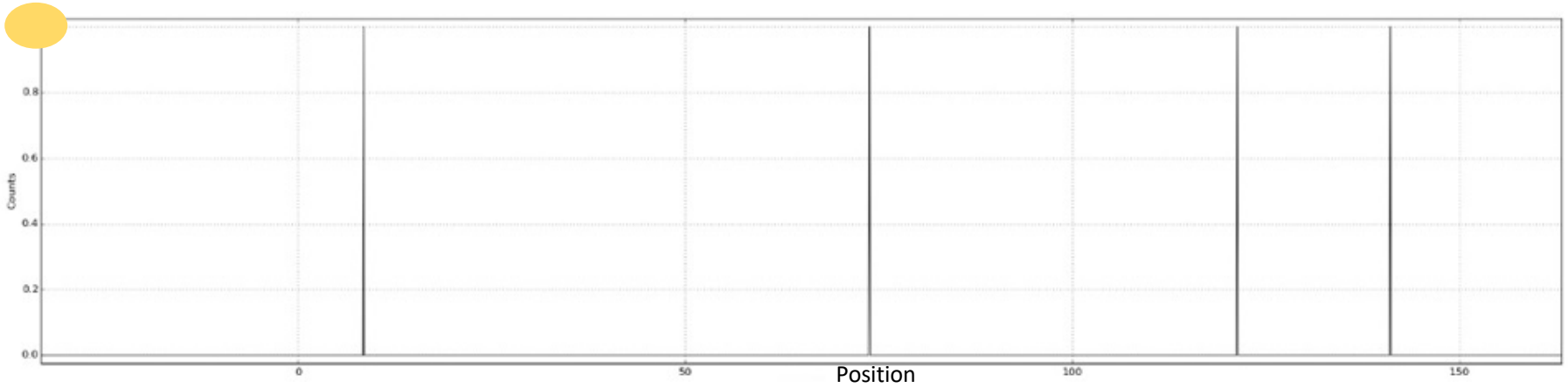


Thanks to ID18 beamline, A. Chumakov *et al.*

5) First application

Machine Development Time (MDT) with ID18 users to verify the bunch purity (7th March 2022)

- **After optimization** ➡ **no impurities**, but few peaks linked to cosmic-ray pollution



Thanks to ID18 beamline, A. Chumakov *et al.*

6) Conclusions

It is fun to **explore the extremes like one single electron** in both control and measurement with a simple **low-cost PMT** and the **visible-light system**.

The **dark-current** is in general our enemy, it is **usually suppressed by SY-cleaning system**, and it is **ultra-weak** (~100 electrons), can **never be measured with ordinary devices**, but it can disturb **users** that **impose high bunch-purity.**

With this simple device, we can **optimize the cleaning process** and **minimize the electron pollutions**, but only **during MDT** for the moment. The ID18 users verified the optimized cleaning performed with the help of our system.

The ultimate goal is to be able **to measure during USM the purity,** up to **10^{11} dynamic range** with the visible-light system, to install a **better PMT** and then a **Time-Correlated-Photon-Counter (TCPC)**. Such a dynamic range has so far remained impossible for our ASD-Diag. purity measurements.

Many thanks to the Beam Diagnostics, Accelerator Control Unit, Beam Dynamics and Beam Operation groups for technical support.

Many Thanks
for your Attention!

Questions?