# Beam Loss Monitor activities at CTF3 and the Australian Synchrotron

**CLIC Workshop**
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all CTF3 operators …


# Outlook

**Optical fibre BLM**

1. The OBLM system

2. Test Beam Line (TBL)
   - Long pulses
3. Australian Synchrotron  Light Source (ASLS)
   - Single bunch
   - Multi bunch

Position resolution

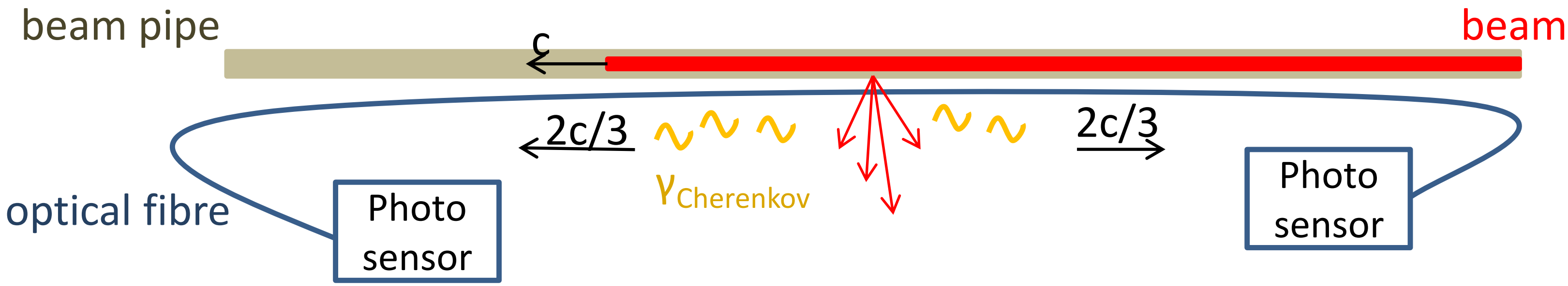
4. Two-Beam Module (TBM)
   - First  beam loss crosstalk studies
5. Dogleg experiment
   - RF cavity induced background

BLM Background

6. Conclusions

# Optical fibre Beam Loss Monitors (OBLMs)

- OBLM system is based on Cherenkov light
  - ✓ Cost-effective, n,γ insensitive, covering long distances → ideal for linacs
- Optical fibre:
  - Pure Silica, high OH content, variable core Ø depending on application
  - Nylon jacket to protect against: humidity, ambient light



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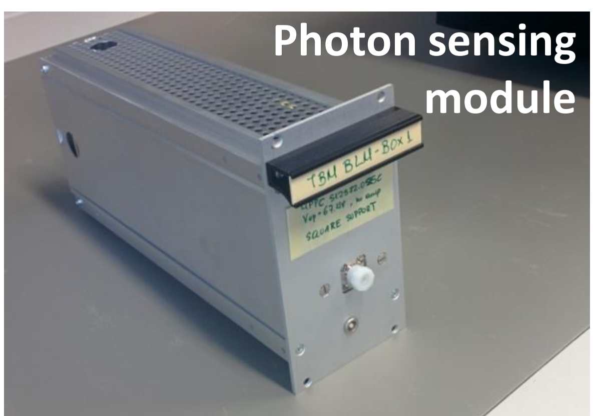
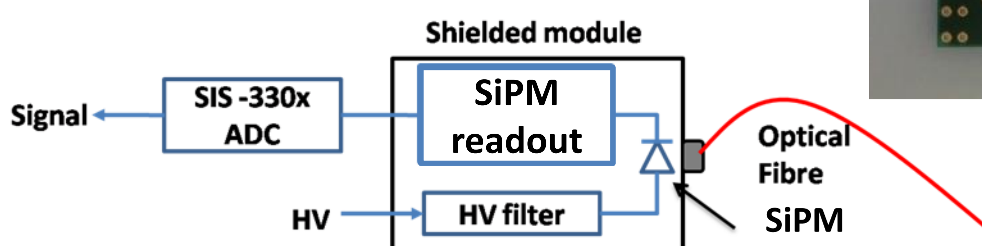
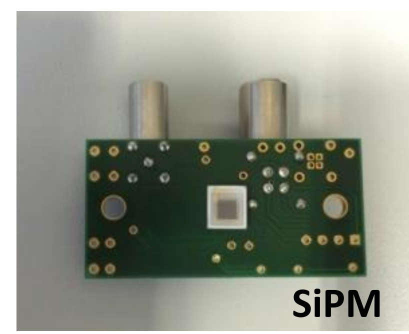
- Development of **custom made , shielded** photon sensing modules
  - Silicon PhotoMultiplier (SiPM) (3x3 $mm^2$, default 40000 pixels, G $=10^{+5}$ - $10^{+6}$)
  - Low pass filters (bias input) for noise filtering



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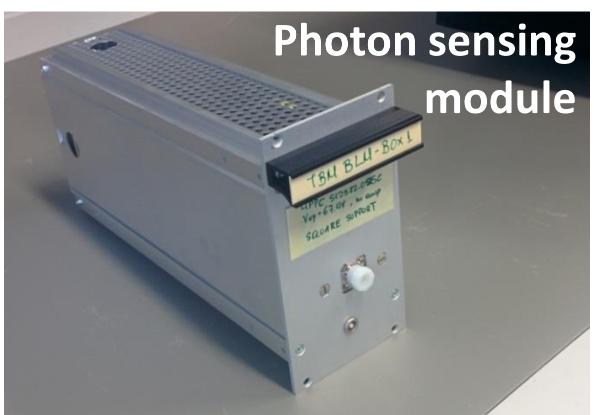
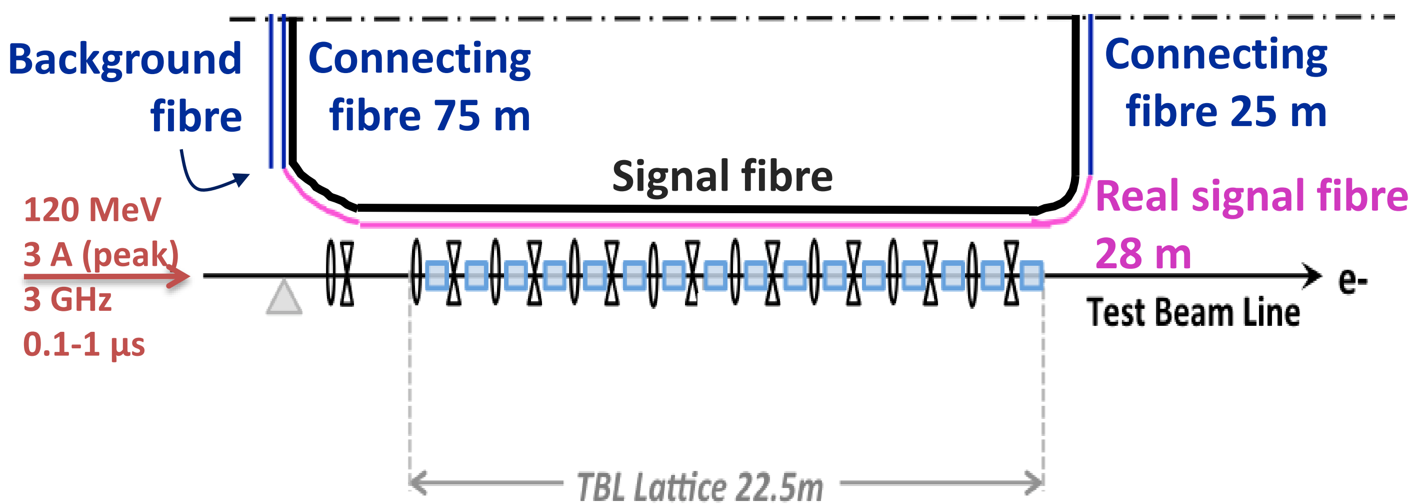
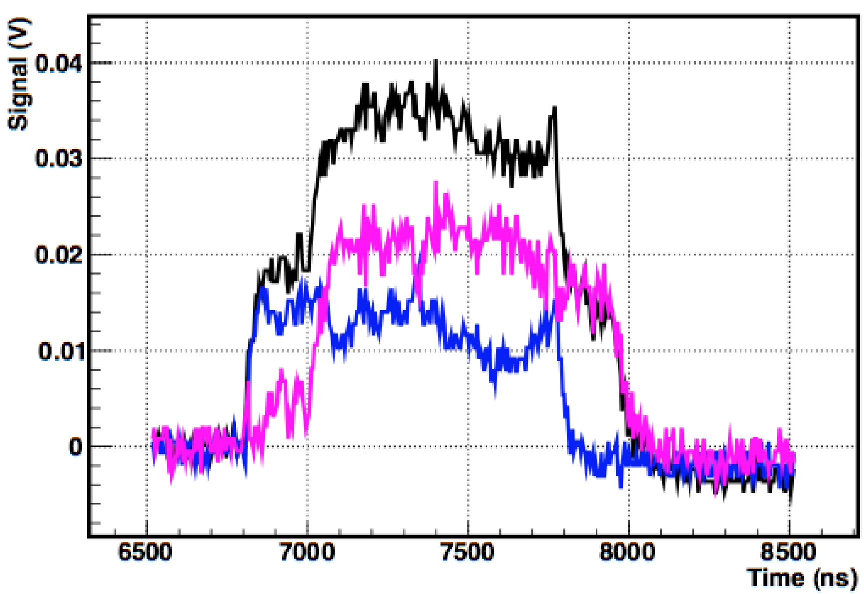
  - Low pass filters (bias input) for noise filtering
- Design of RF shielded chassis to include the modules
- High sampling (1-4 GS/s) and high bandwidth (250 MHz - 2 GHz) ADCs




# OBLM at the TBL

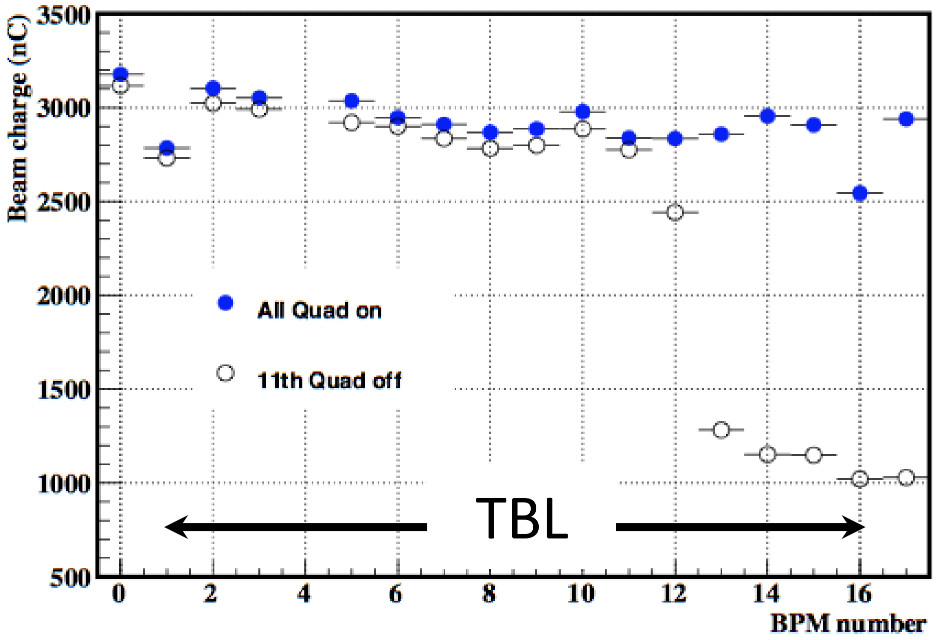



## Signal subtraction to account for showers from TBL only




# TBL: losses with long bunch trains

- **Observing losses from a 1μs long pulse**
  - Controlled losses generated by switching off quadrupoles
  - BPM signals to correlate



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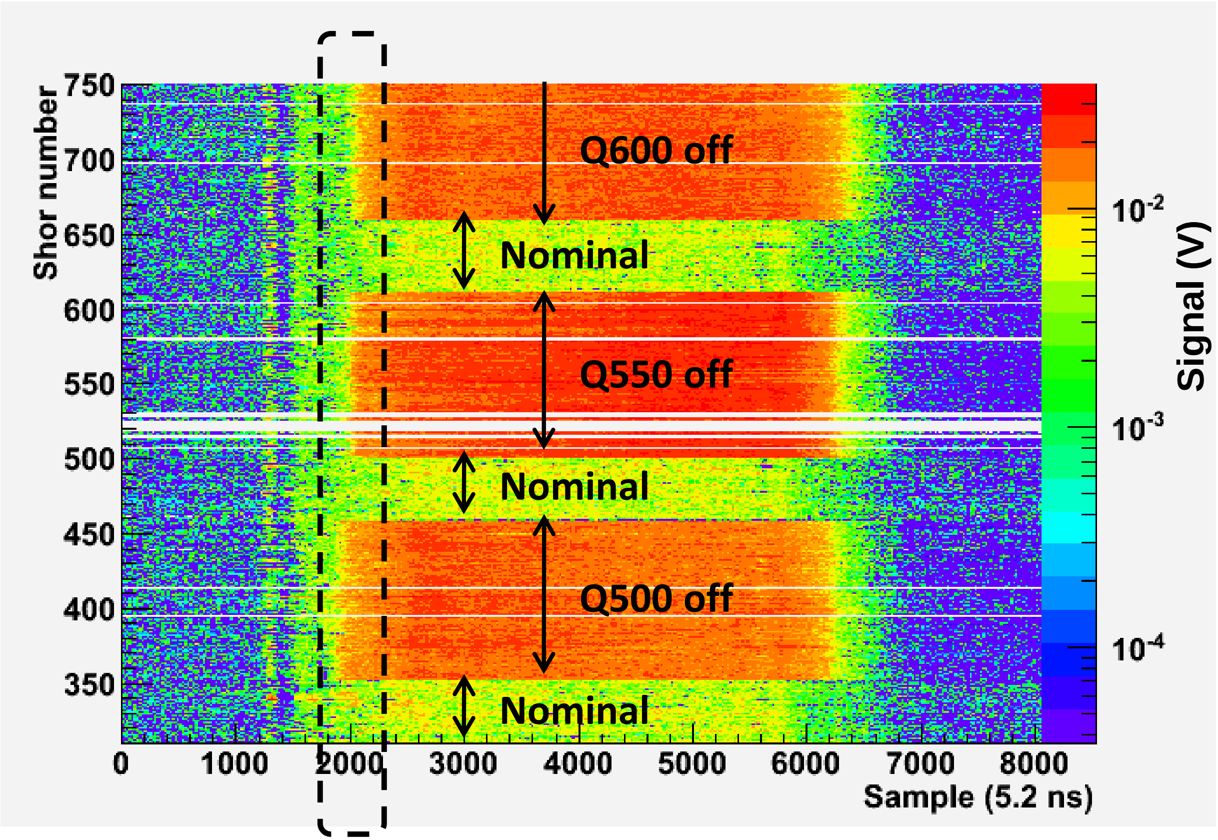

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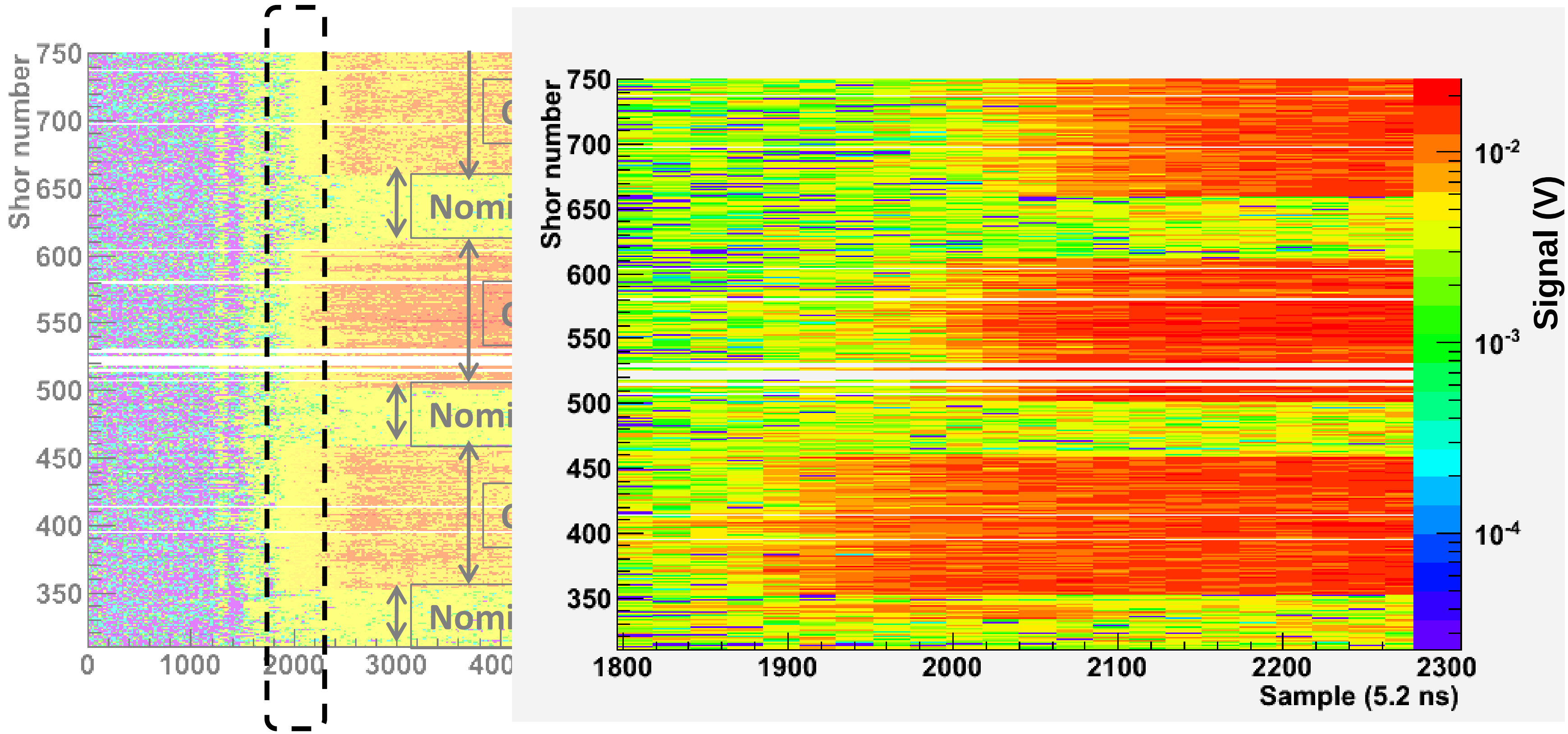
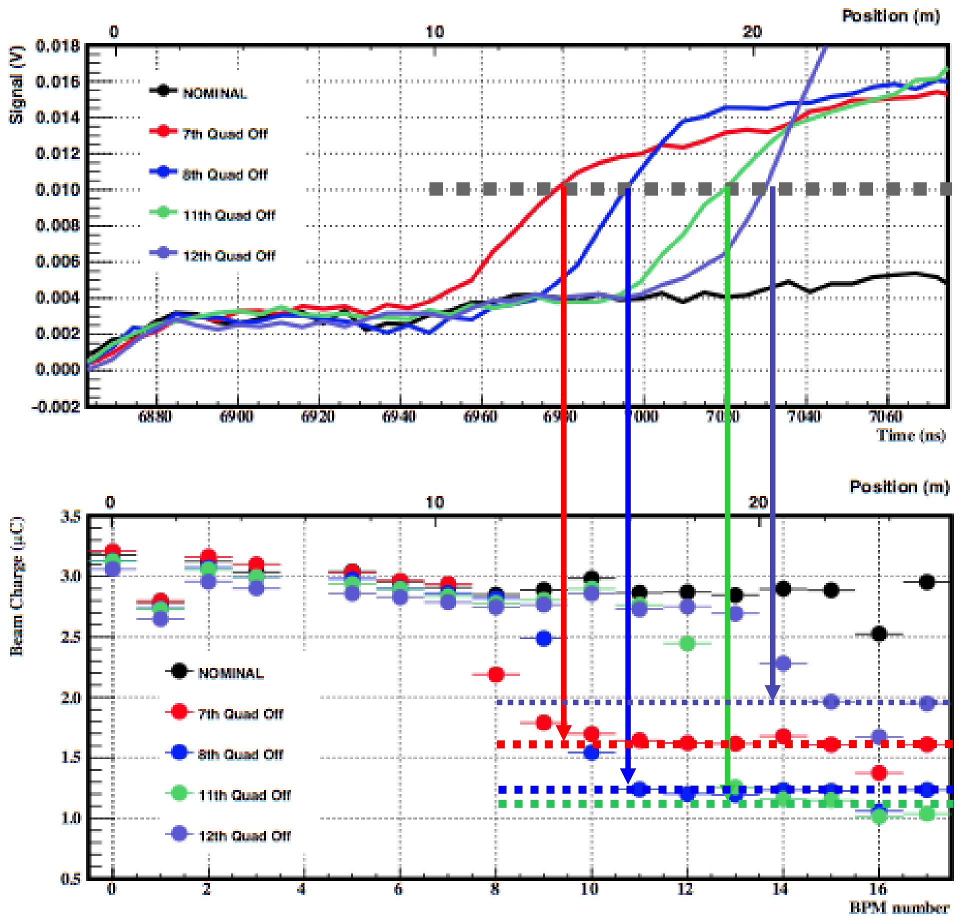


# CTF3: losses with long bunch trains (II)

**Determination of loss location from signal leading edge**

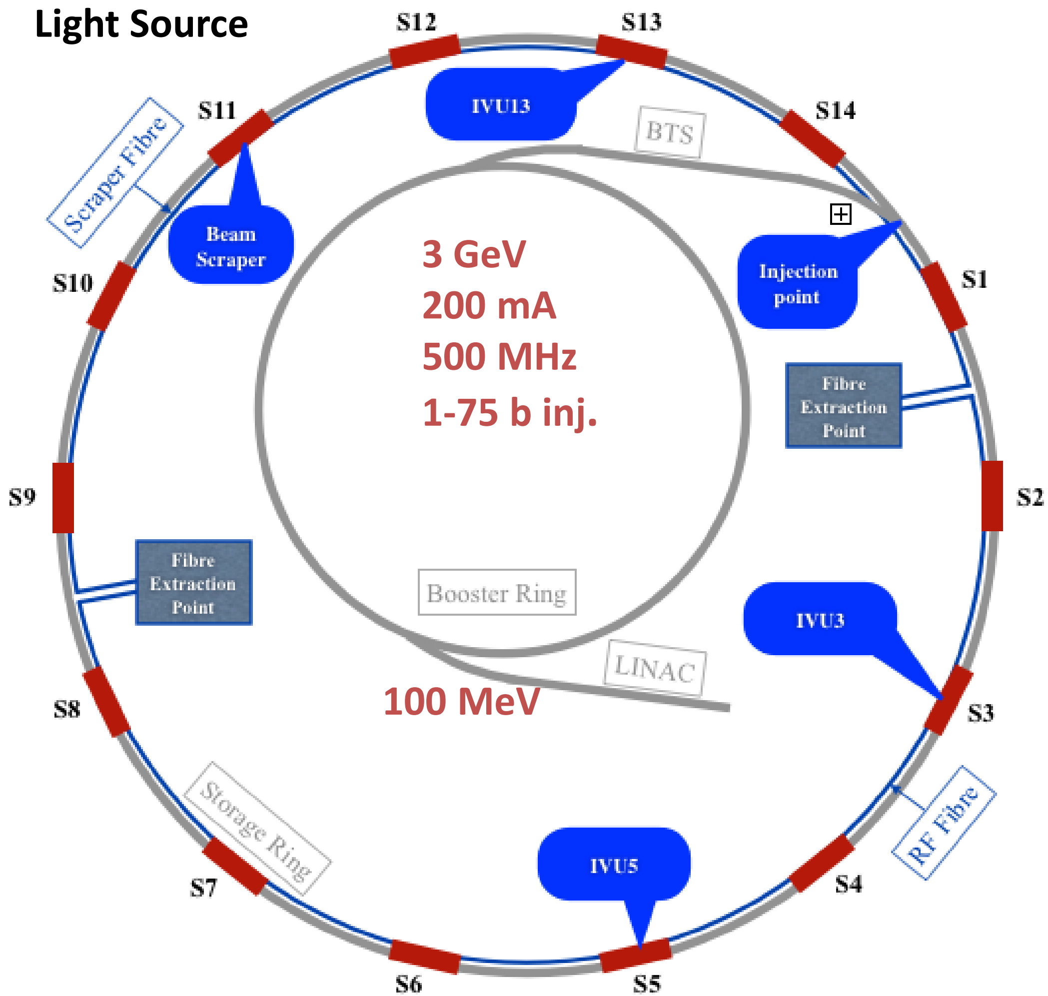
- ○ Good qualitative agreement between oBLM and BPM profile loss measurements
- ✓ Localisation of loss down to (below) 2 m achieved!




**TBL Plans for 2016:**
Position resolution for long bunch trains, multi-loss location

# Installation at the ASLS

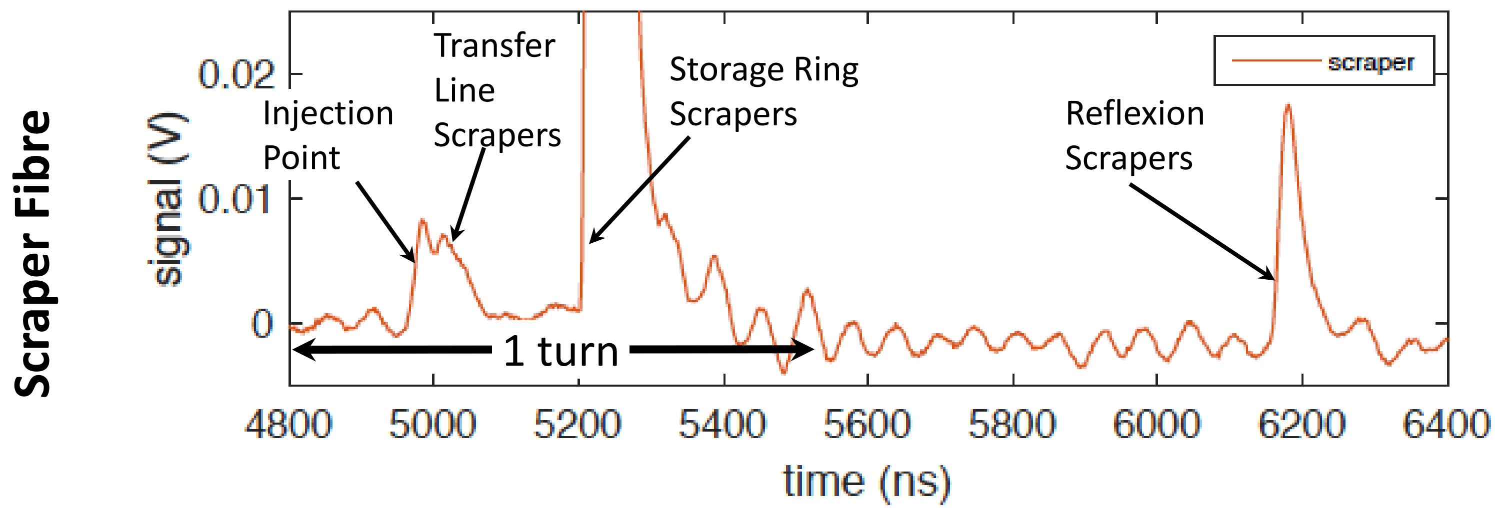
**Australian Synchrotron Light Source**

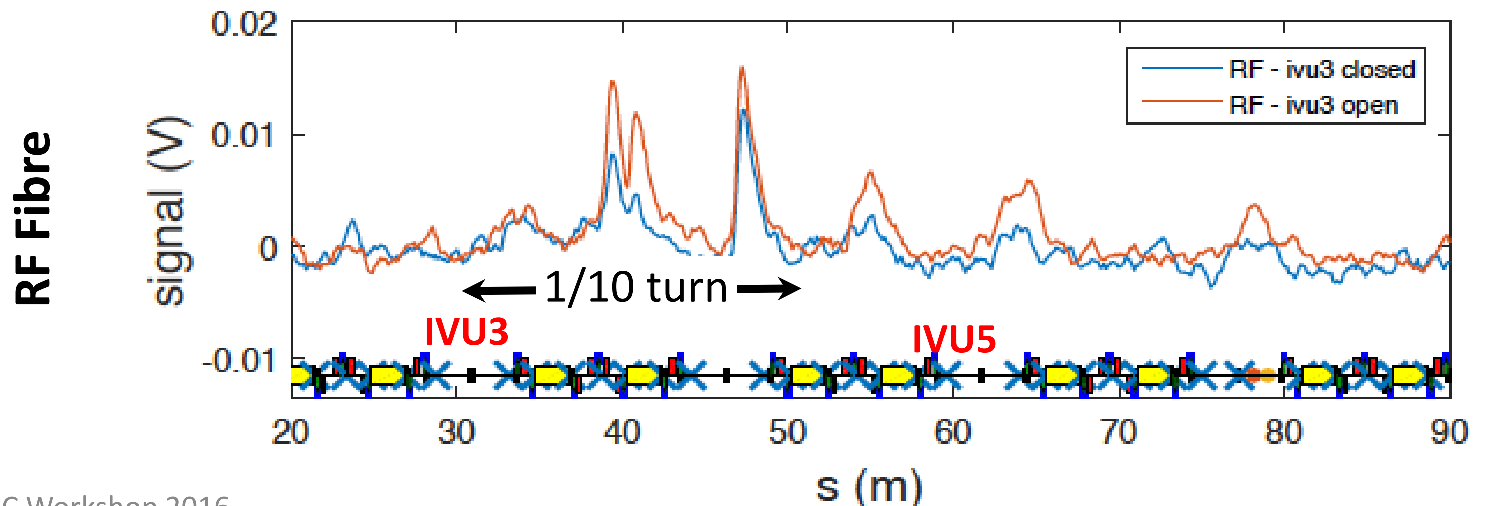



- 216 m storage ring
- Many similarities to the CLIC Damping Rings
- 2 optical fibres covering the ring
  - 200 µm core Ø
  - 125 m
- Scraper fibre
  - Scraper
  - Injection point
- RF fibre
  - 2 In Vacuum Undulators (IVUs)
  - 2 RF cavities

# AS: understanding beam losses, single - bunch

**Multi peaks observed due to losses in different positions**

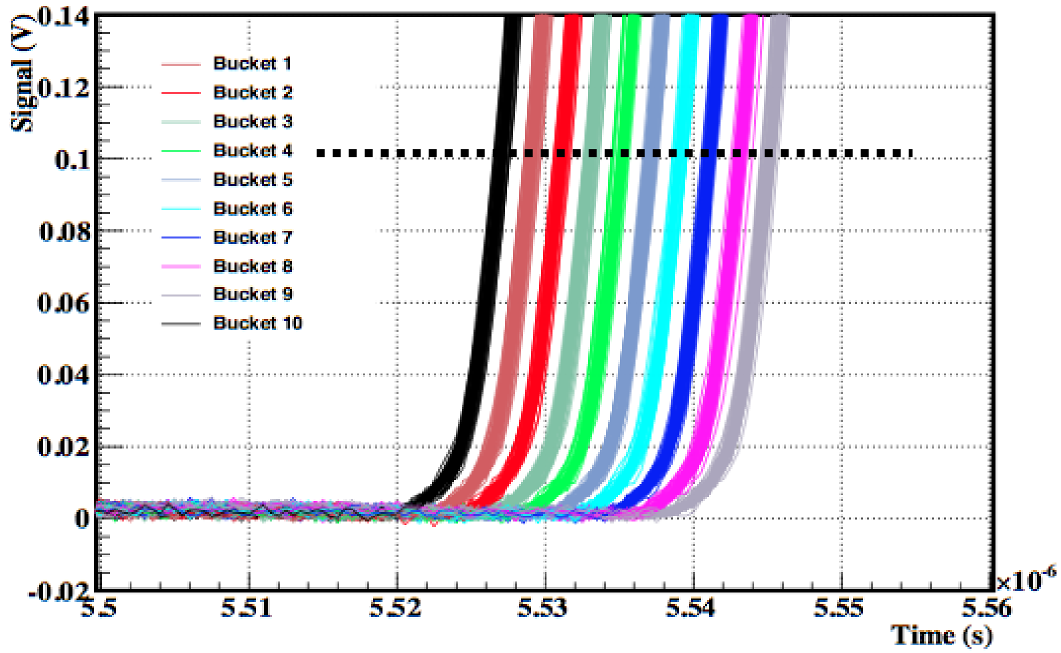


# AS intrinsic time resolution

- Single bunch injection
  - Consecutive filling RF buckets 1-10
  - Looking at **raising edge** of losses at scrappers (well defined location)

**One bucket (2 ns) shift disentangled shot by shot!**

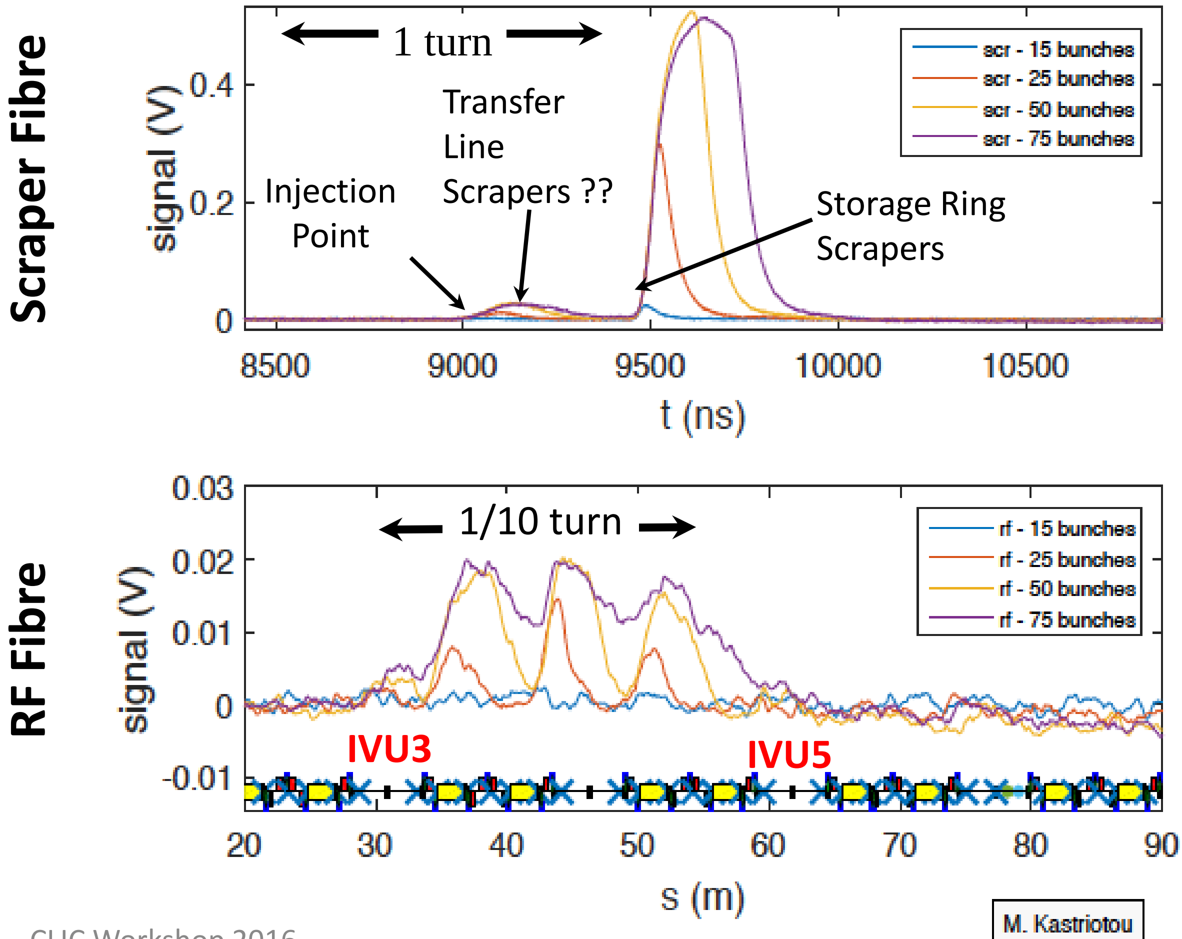



Position resolution <10 cm can be achieved !

# AS: understanding beam losses, multi - bunch

**Multi peaks observed due to losses in different positions**

- Rising edge still provides loss location information
- Signal de-convolution required for losses in near positions




- Position resolution for multi-bunch and sensitivity for steady-state losses under investigation

# BLMs at the TBM

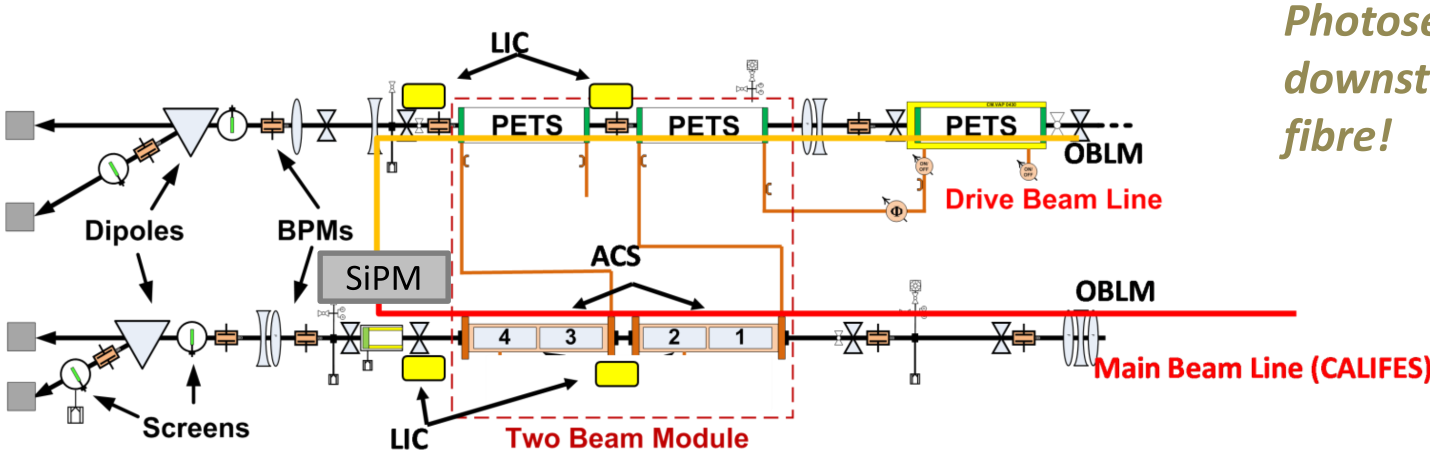
Installed detectors:

- **Little Ionisation Chambers (LIC)** (CDR suggested)
- **OBLMs + 14400-pixel SiPMs**

Motivation: measurement of BLM so-called beam loss “crosstalk” on the TBM

- “Crosstalk”: losses of one beam line detected by the BLMs protecting the other
  → limitations in sensitivity of CLIC BLMs
  → study of the radiation on one beam line due to beam losses of the other

| | | |
|---|---|---|
| MB | 2 LICs 5 cm downstream of the AS | 7 m long Ø365 μm $SiO_2$ optical fibre, 4 m upstream the TBM |
| DB | 2 LICs 10 cm downstream of quads | 5 m long Ø200 μm $SiO_2$ optical fibre, 2 m upstream the TBM |

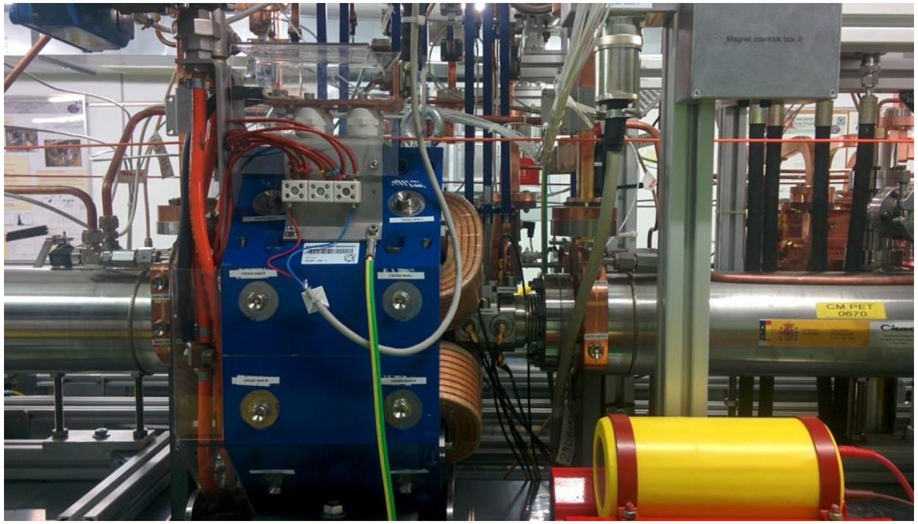



*Photosensors at the downstream end of the fibre!*

# Measured crosstalk

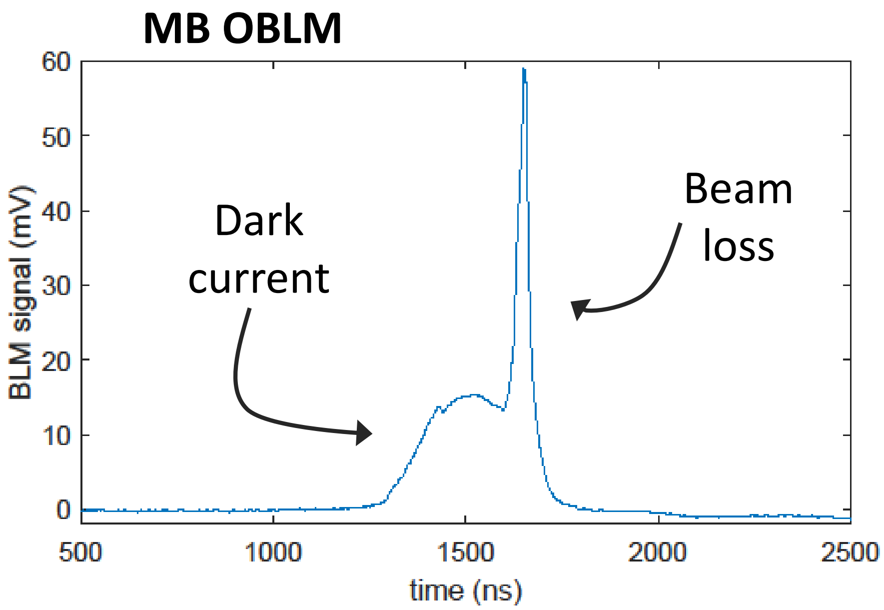
- Average beam charge calculated from the BPMs
- Crosstalk calculated as: $Crosstalk_{1\rightarrow2} = Q_2/Q_1$

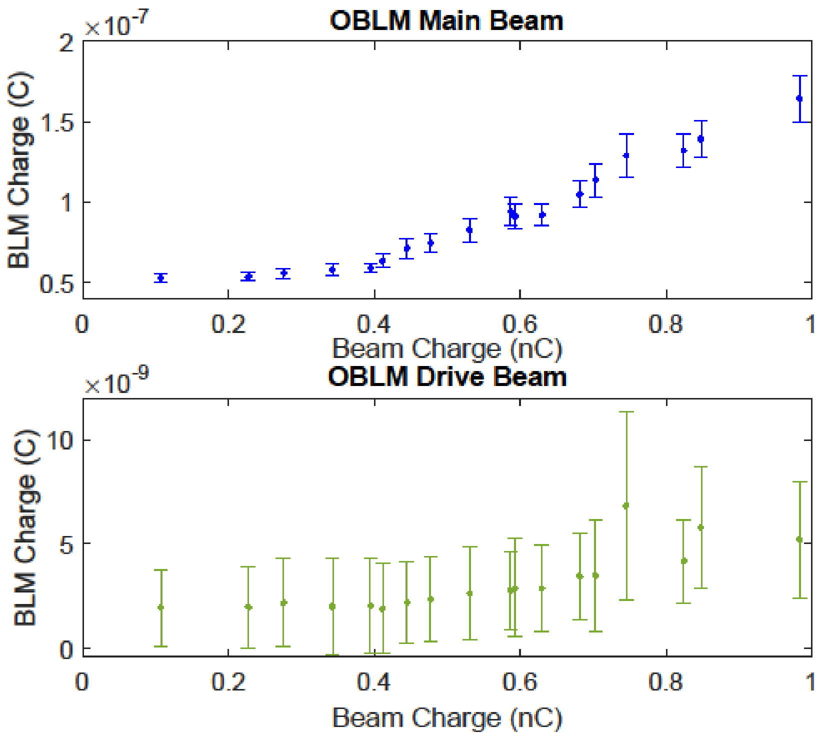
  BLM integrated charge
- 3 types of measurements:
  1. Main Beam (on) ⟶ Drive Beam (off),
     1. Good MB transmission
     2. Loss scenario: Insertion of OTR Screen in Califes
  2. Drive Beam (on) ⟶ Main Beam (off)



# Crosstalk during nominal Main Beam

- Califes good beam transmission
  - 100 shots acquired for increasing beam current
  - Losses detected by OBLMs only
  - High OBLM sensitivity ⟶ Dark current from electron gun monitored



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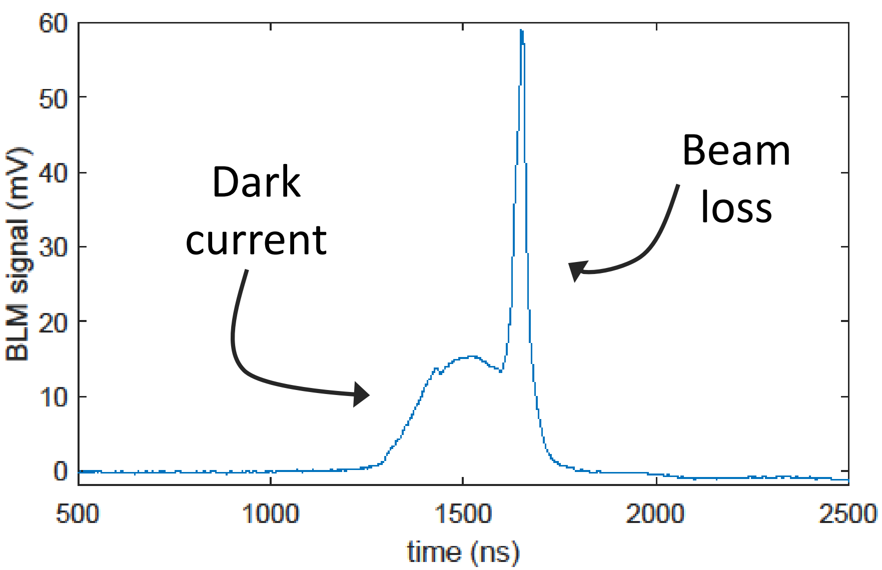
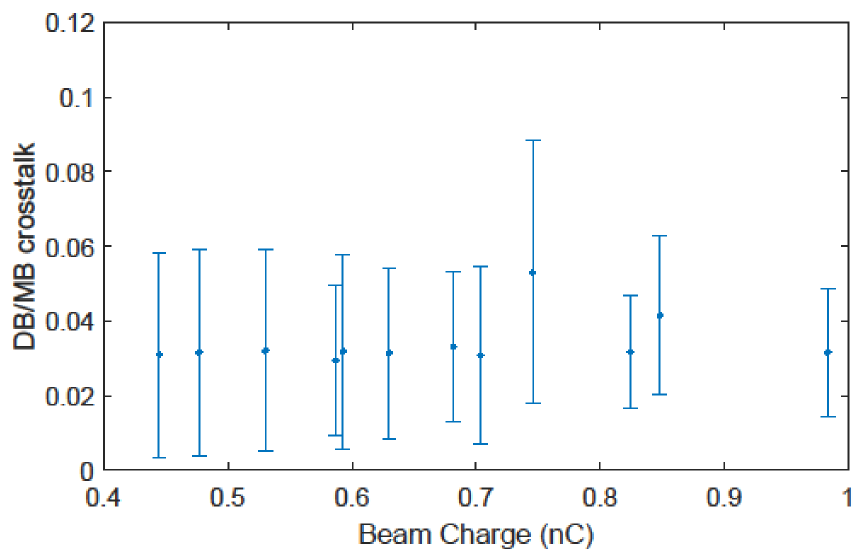
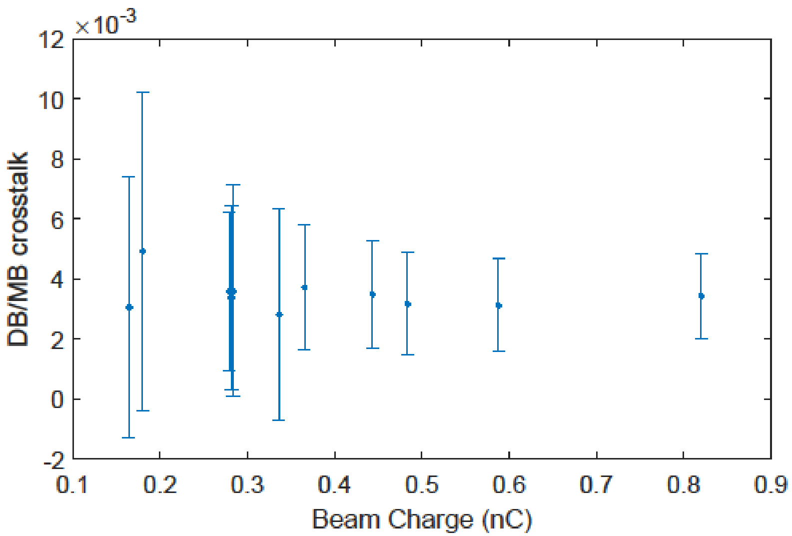
  - Crosstalk measured at **3.4 %**

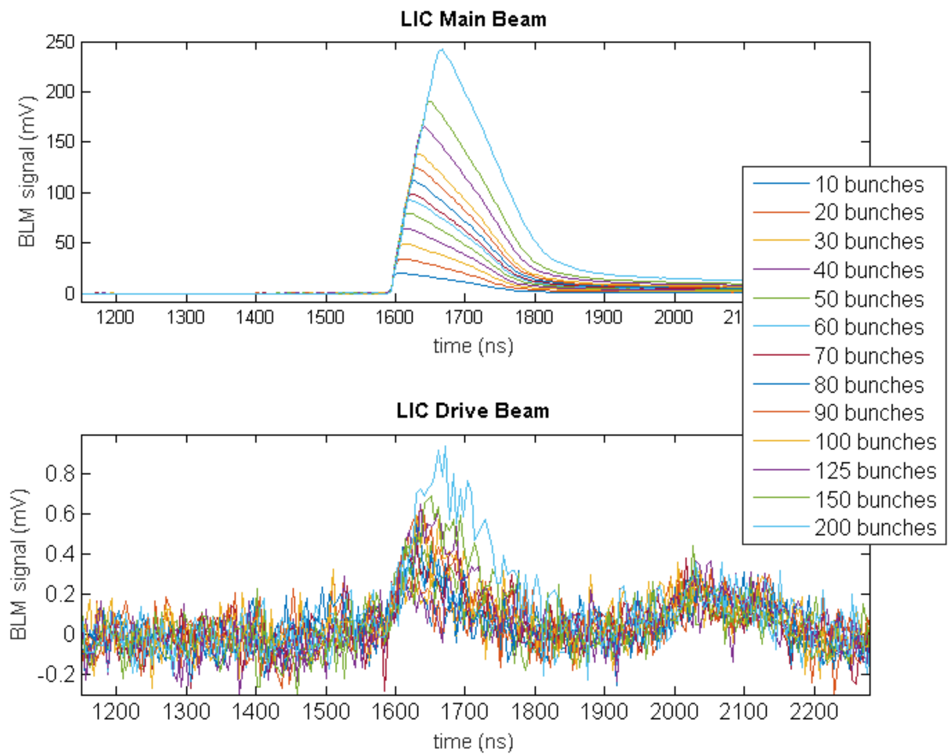


# Crosstalk during OTR screen insertion

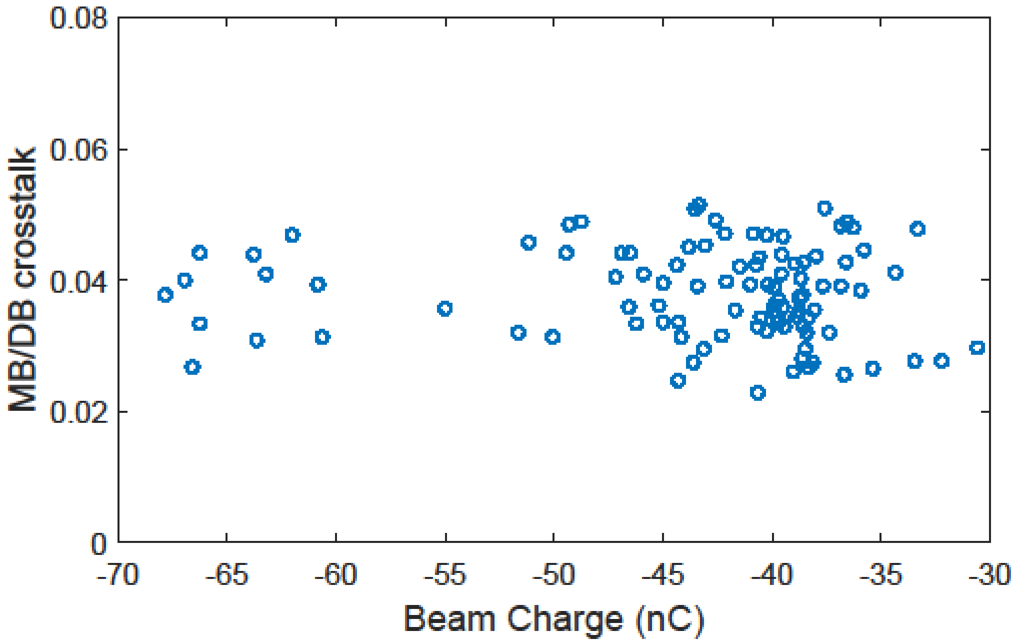
- OTR screen insertion in Main Beam to induce losses
  - OBLM photodetector saturates
  - Losses detected by LICs
  - Crosstalk **<1%**



# Drive Beam crosstalk to the Main Beam

- One set of measurements (100 shots), low Drive Beam current, 1.12 A
  - Bad beam transmission
  - OBLM photosensor saturates
  - Losses detected by the LICs
  - Crosstalk **~4 %**




**TBM Plans for 2016:**

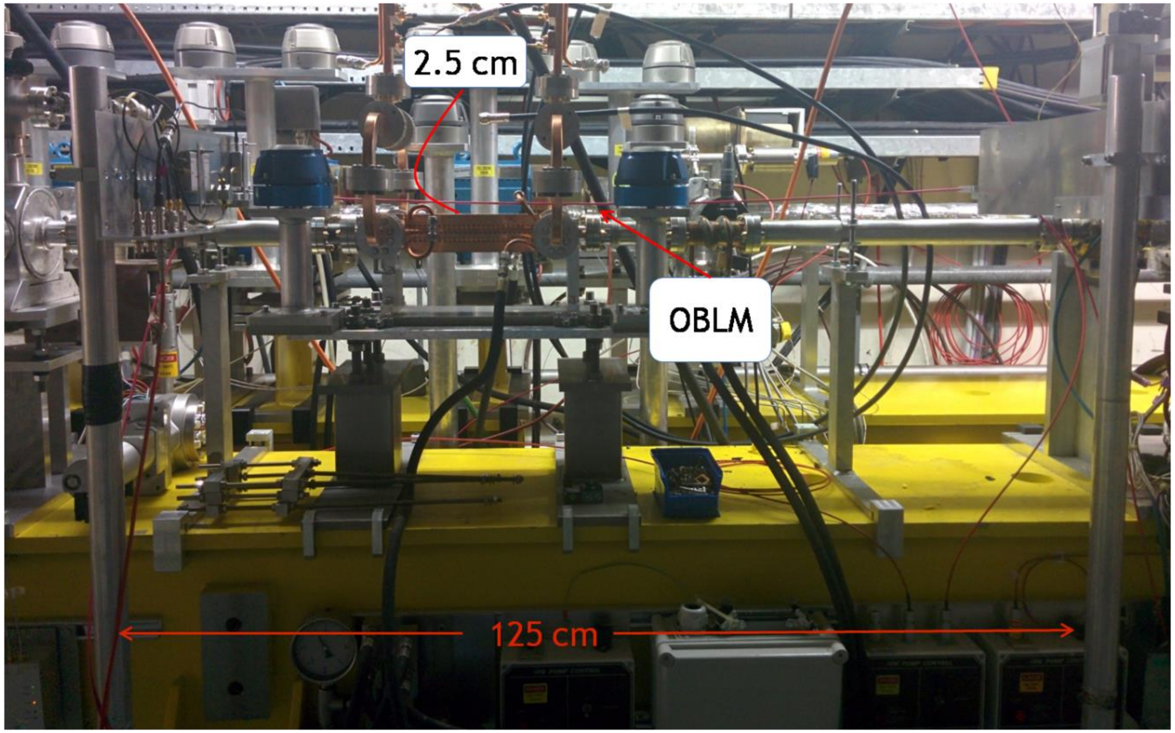
- Repeat with new setup (new 90000-pixel SiPMs)
- Cover the downstream side of the TBM
- "Read" the upstream of the fibre
- More conditions (good DB transmission, combined beam, TBM operation etc)

# Installation at the dogleg – RF cavity background

mA, accelerated

100 A, EM field collapses

- More than 140000 RF cavities in a 3 TeV CLIC
  - Background from electron field emission and RF breakdowns?
- **Dark current sensitive system** installed at the dogleg experiment (T24)
  - 900 µm OBLM + 3600-pixel SiPM+ transimpedance amplifier

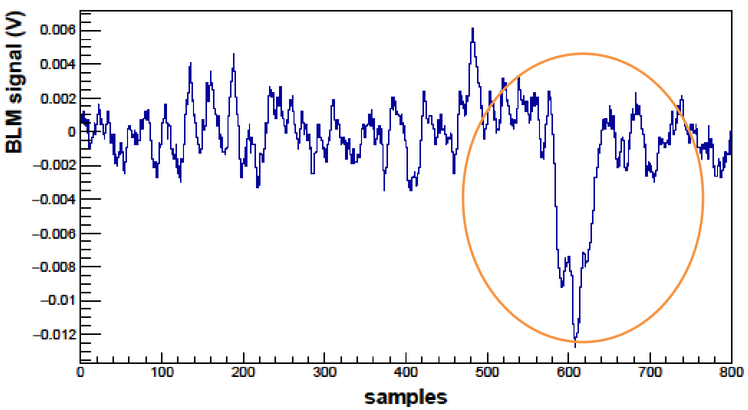


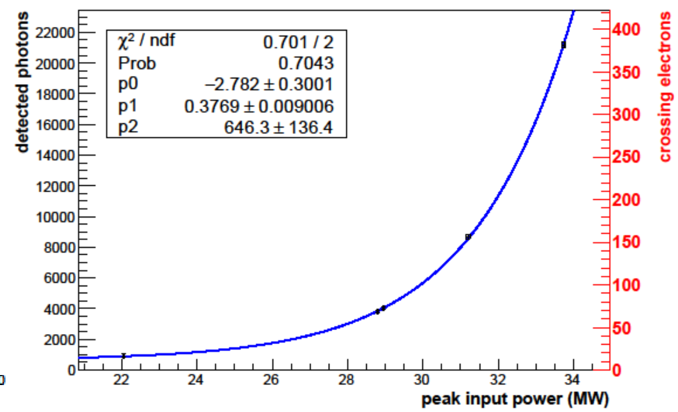

*"Field emission and RF breakdown current measurements using optical fibre BLMs"*, M. Kastriotou, Tue, Session 3

# Measurements of RF cavity background

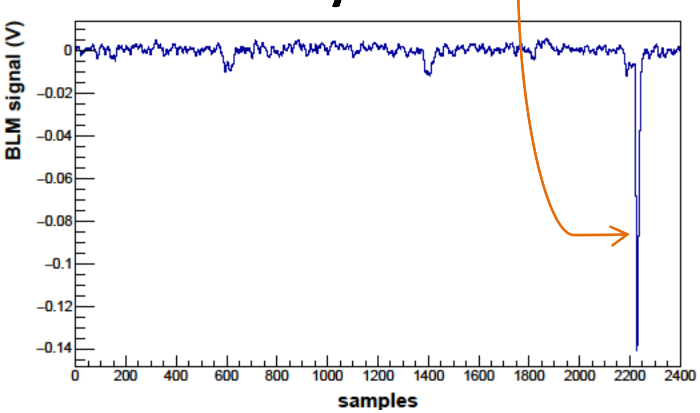
- Potential limitations due to RF cavity electron field emission

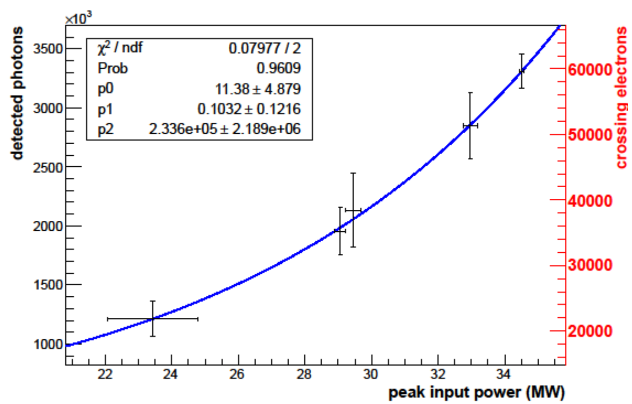
**Sensitivity to field emitted electrons** → RF cavity diagnostics tool ?




**Sensitivity to RF breakdowns**




**Dogleg Plans for 2016:**

- Continue with TD26
- Loaded/unloaded comparison

✓ Diamond detector installed

# Conclusions

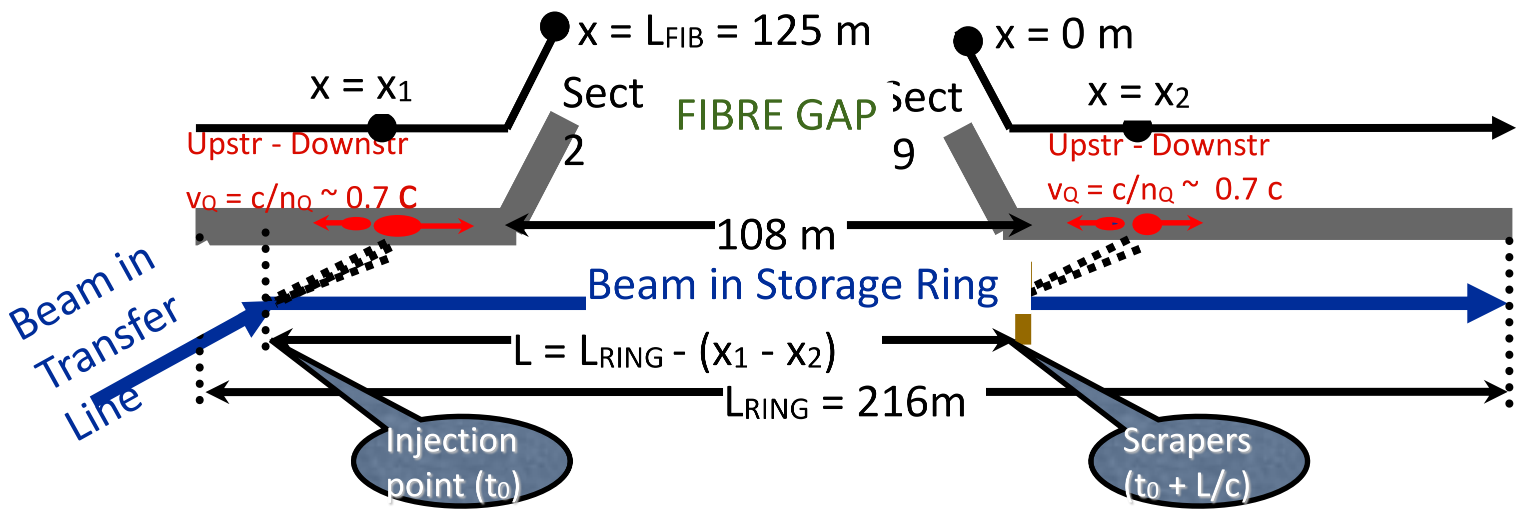
- First attempt at loss location reconstruction with long (1μs) pulses
  - ✓ Resolution better than 1.4 m achieved for single loss location
- OBLM system was demonstrated suitable for the CLIC damping rings
  - ✓ Position resolution below 10cm can be achieved for single bunch
  - ✓ Sensitivity requirements previously verified (IBIC14)
- First measurement of beam loss crosstalk to BLMs at TBM
- Potential limitation of BLMs due to RF cavity dark current and RF breakdown

*Thank you for your attention!*

*Back up*

# Understanding Beam Losses

Most studies performed on losses generated in the first turn



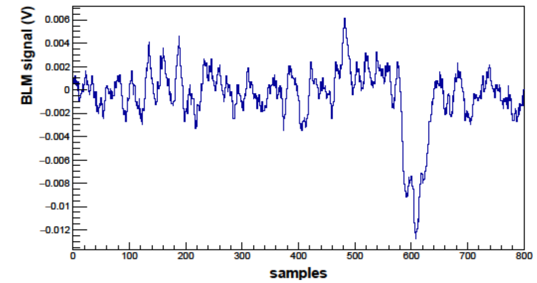

- **Two loss points on opposite sides of FIBRE GAP**

$$\Delta x = \frac{L_{RING} - c\Delta t}{1 + n_Q}$$

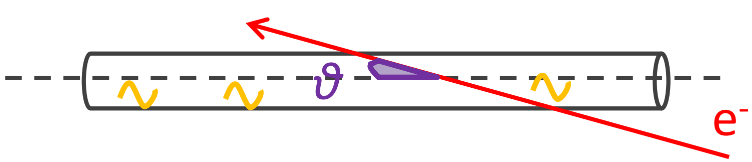
- **Two loss points on same side of FIBRE GAP**

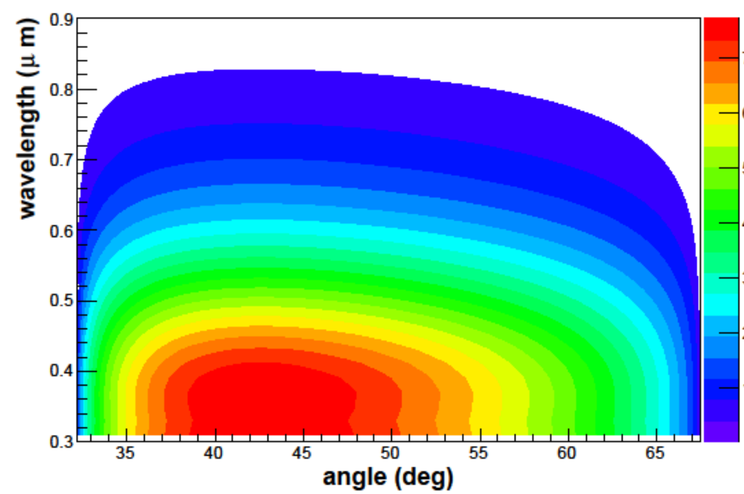
$$\Delta x = \frac{c\Delta t}{1 + n_Q}$$

# Calculations



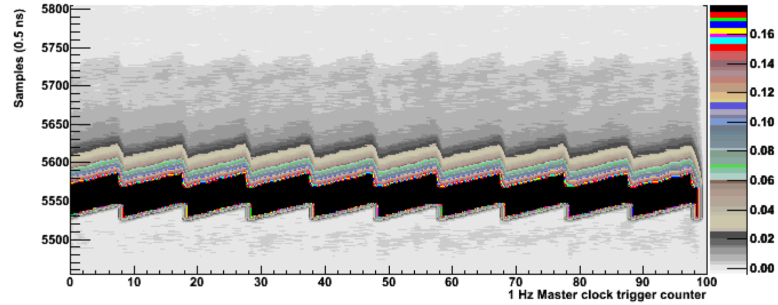

- Mean value of the detected charge (C)
- Calculation of the Cherenkov photons that have given this signal
  - Readout circuit design
  - SiPM Gain
- Estimation of the number of electrons that, if crossing the fibre, would have resulted in this number of Cherenkov photons in the end of the fibre, taking into account
  - Light attenuation in the OF
  - Wavelength distribution of photon yield (~$1/\lambda^2$)
  - Angular dependency of photon yield and photon propagation
  - SiPM efficiency dependence on wavelength
  - <u>Assumption 1</u> : β=1
  - <u>Assumption 2</u> : uniform angular distribution of $e^-$ (0° - 90°)



# AS intrinsic time resolution & Booster phase shift

- Repetition with Booster RF phase shift by 180°
  - $V_{oBLM}(t = t_{photon}) = V_{thr}$
  - $t_{photon}$ → Photon arrival time (to upstream end)

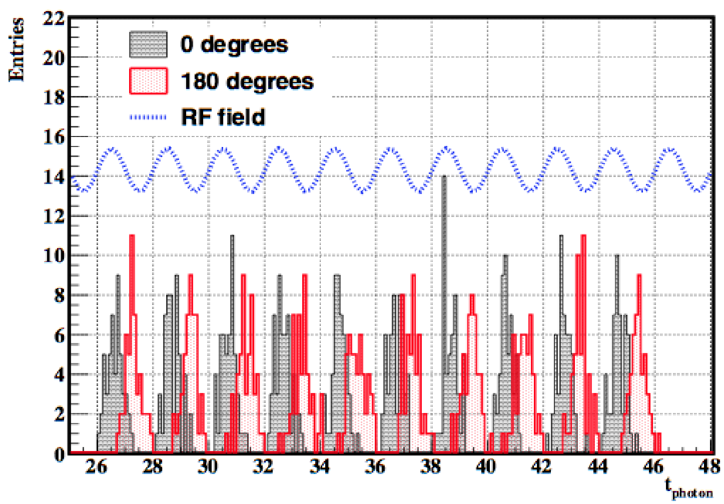


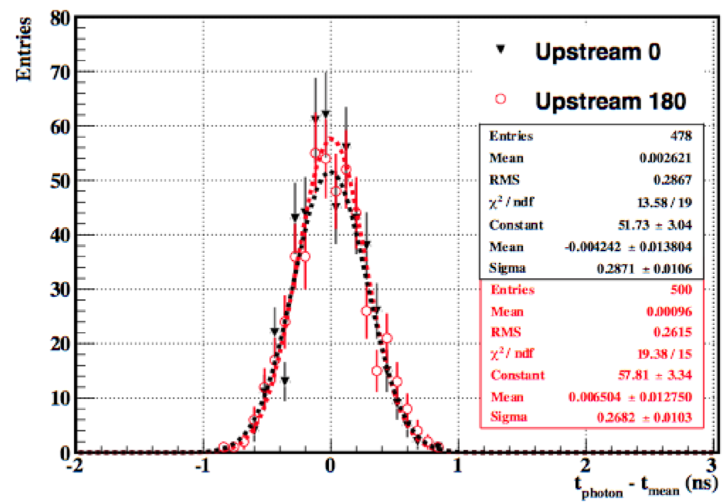

- Time resolution study based on

$$\Delta t = t_{photon} - t_{mean}$$

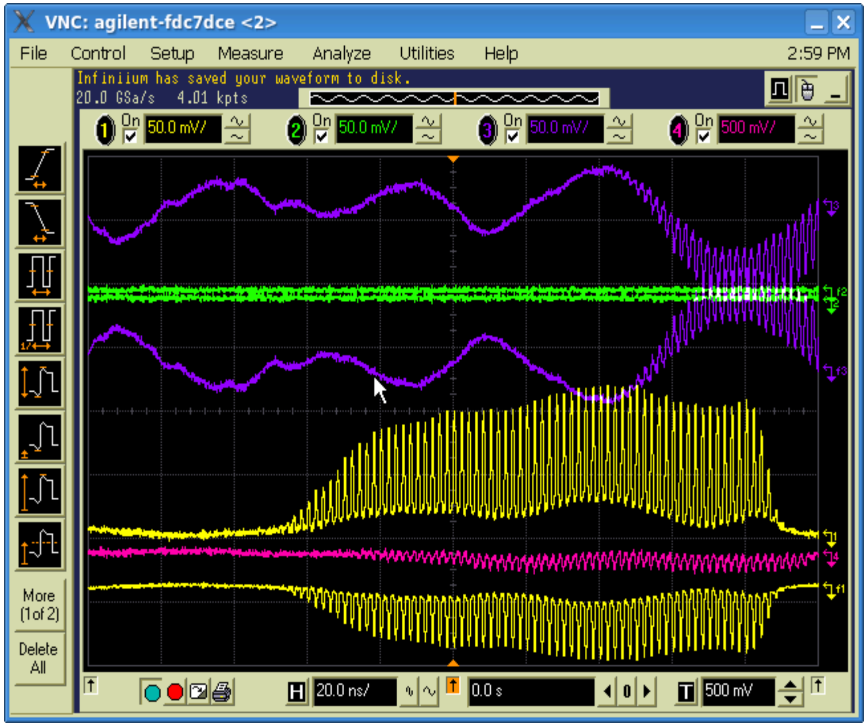
$t_{mean} = t_{off} + n_{bucket} \times T_{RF}$ (central time of $n^{th}$ bucket)

$$\sigma_t \lesssim 300 \text{ ps} \xrightarrow{\Delta x = \frac{c\Delta t}{1+n_Q}} \sigma_x \lesssim 4 \text{ cm}$$



# ASLS multi-bunch current




Current profile of 75 bunch train