Beam Loss Study and Energy Calibration in Taiwan Photon Source

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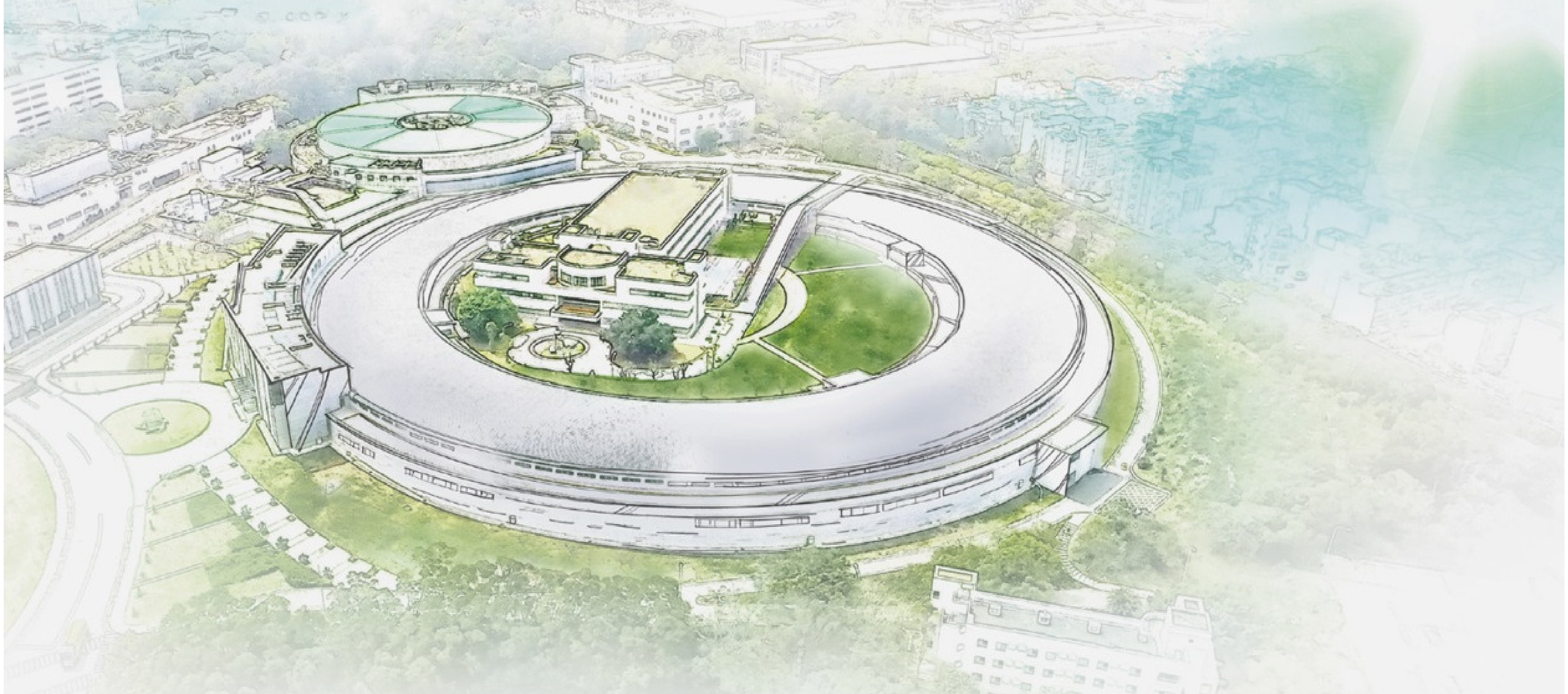


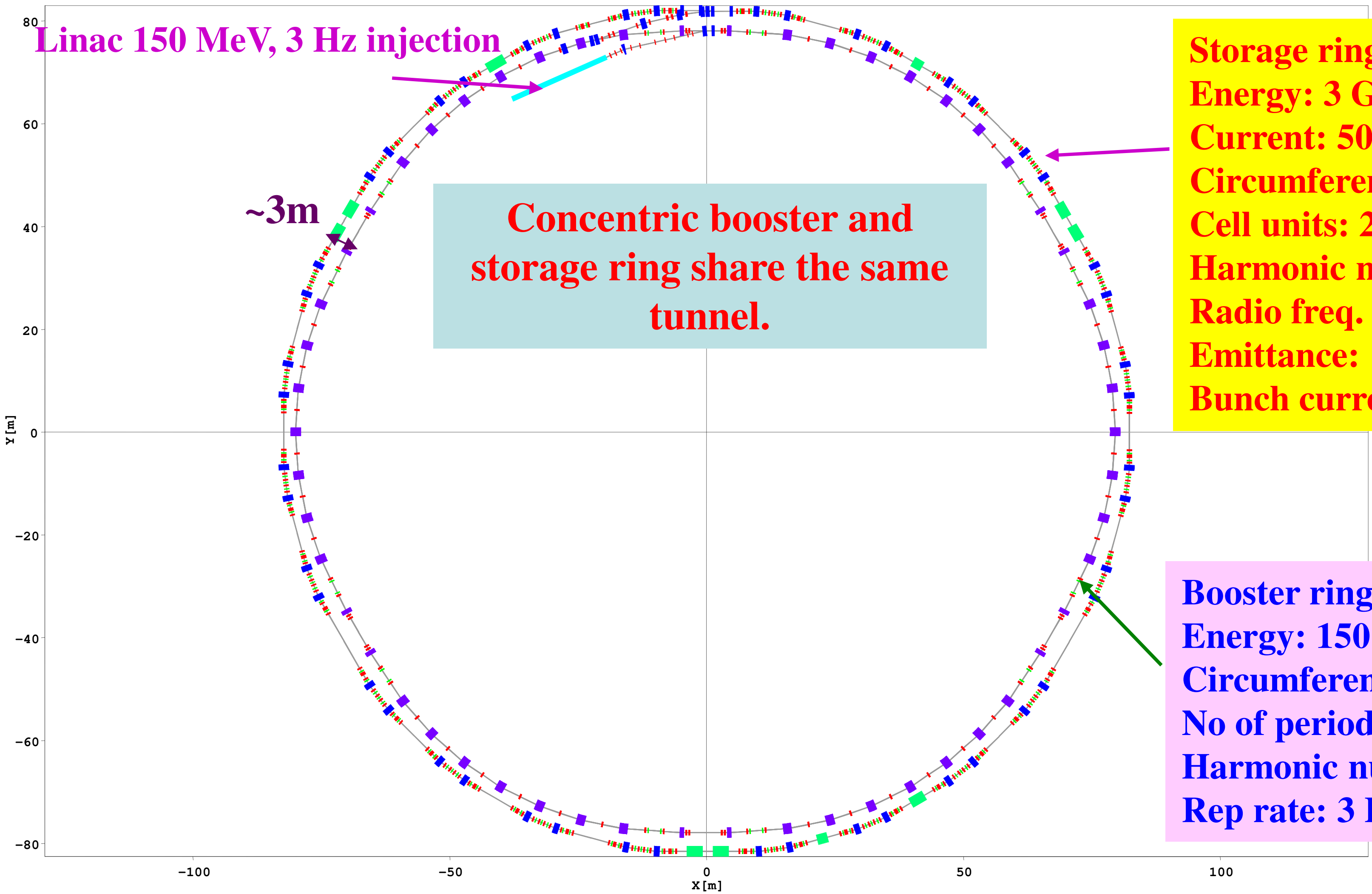
Control and Diagnostic Team of NSRRC

Libera Workshop – May 12th, 2022

Outline

- The layout of Taiwan Photon Source (TPS)
- Beam loss monitors installed at the TPS
- Radiation pattern
  - Beam loss trend at various IUT gap
  - Radiation dose rate vs. Vacuum pressure
  - Beam loss pattern in time domain
- Beam energy measurement
  - Polarization time
  - Beam energy variation with/without feedback
  - Compacting factor
- Summary

The layout of Taiwan Photon Source



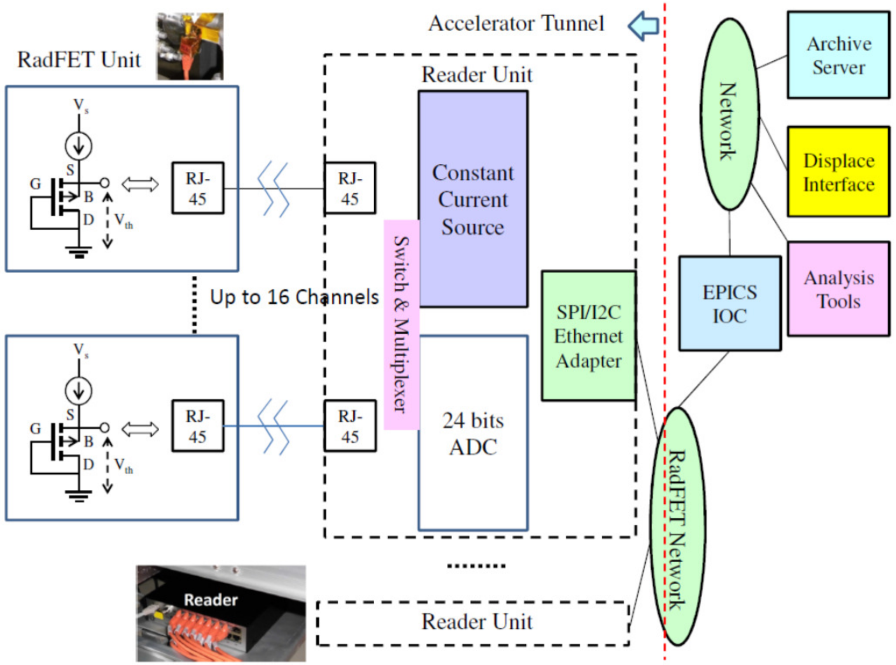
Storage ring
Energy: 3 GeV
Current: 500 mA
Circumference: 518.4 m
Cell units: 24 DBA
Harmonic number: 864
Radio freq. : 499.654 Hz
Emittance: 1.6 nm-rad
Bunch current: ~0.8 mA

Booster ring
Energy: 150 MeV to 3 GeV
Circumference: 496.8 m
No of period: 6
Harmonic number: 828
Rep rate: 3 Hz

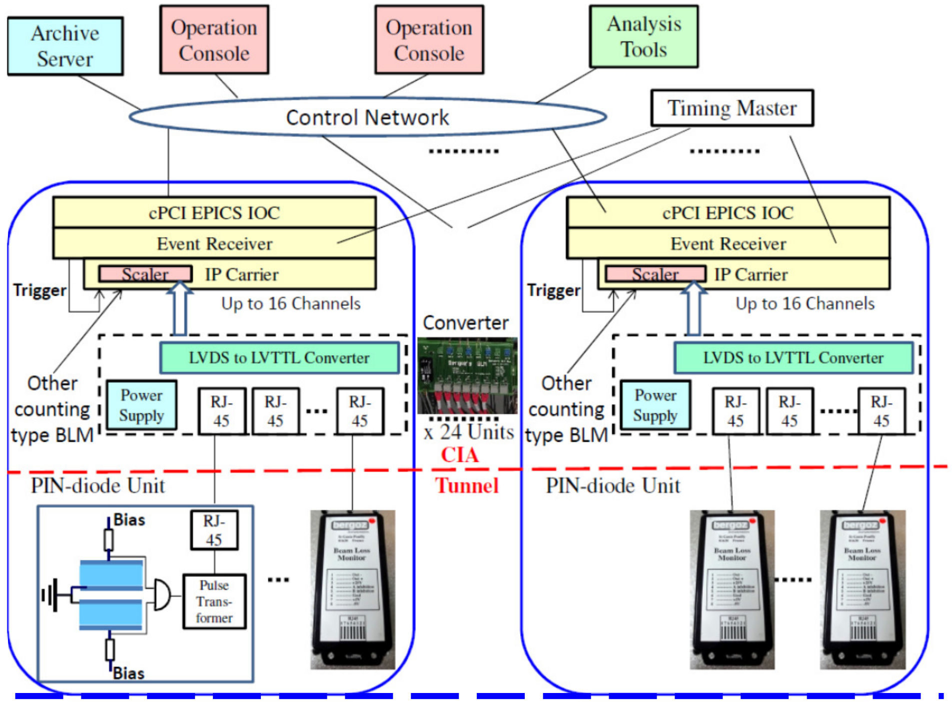
The beam size at 7 m straight center is $120 \times 5\ \mu m^2$ (1% coupling).

Beam loss monitors installed at the TPS

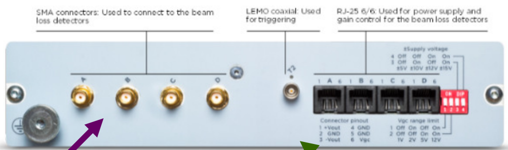
Radiation-sensing field-effect transistors



Dual PIN-diodes



Libera BLM

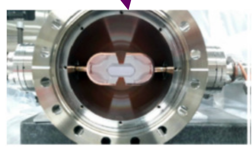


Bunch by bunch feedback

Function Generator

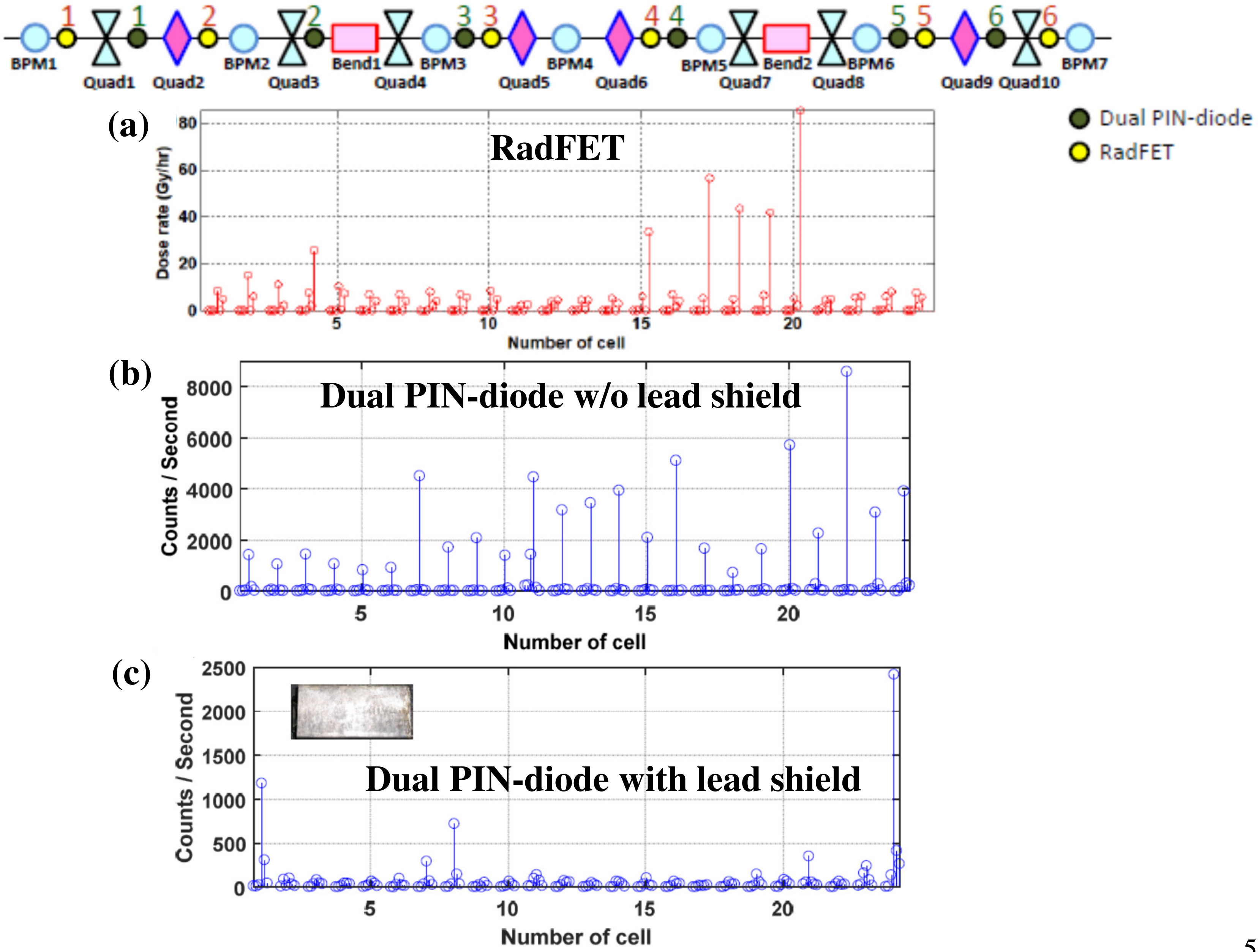
or

Amplifier



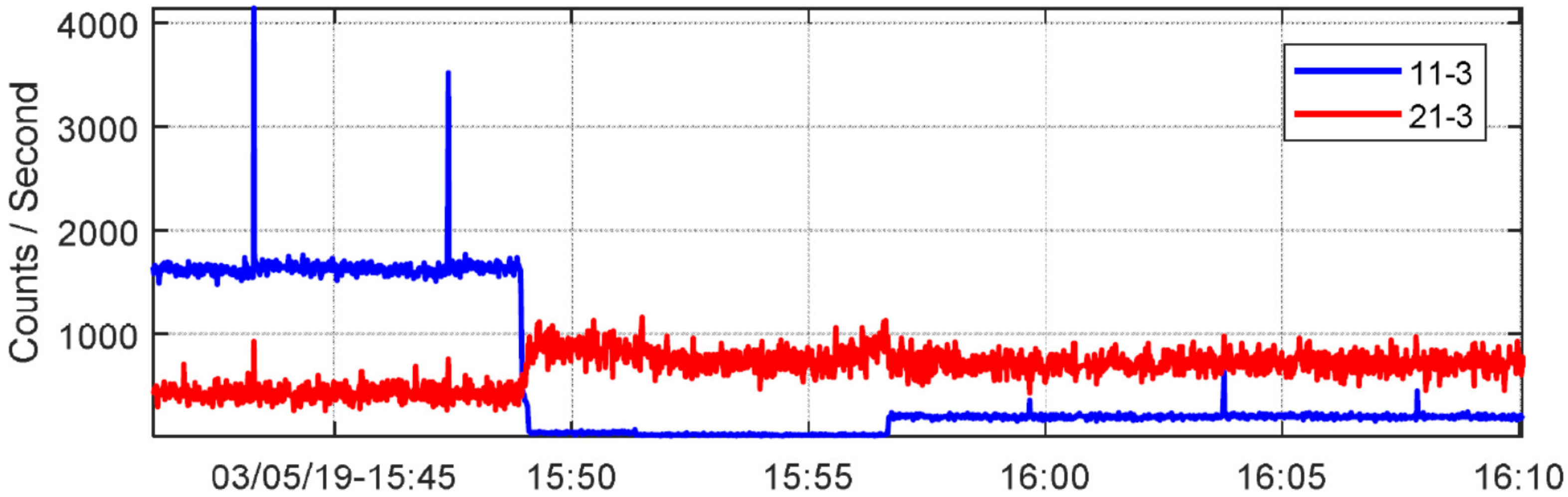
Kicker

Radiation pattern

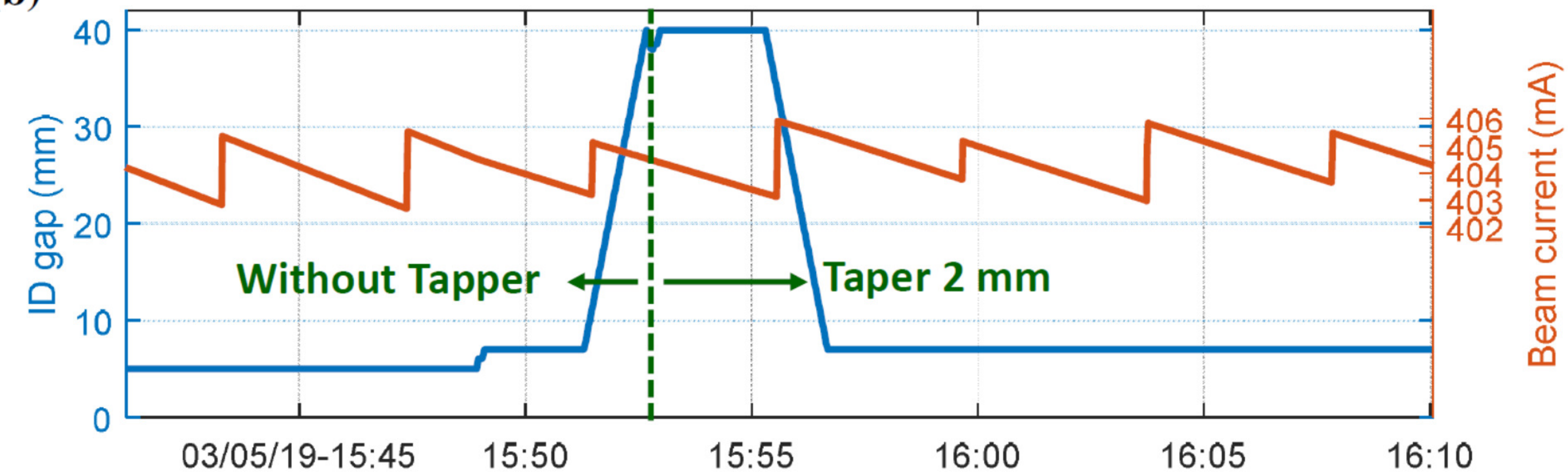


Beam loss trend in various gap of IUT

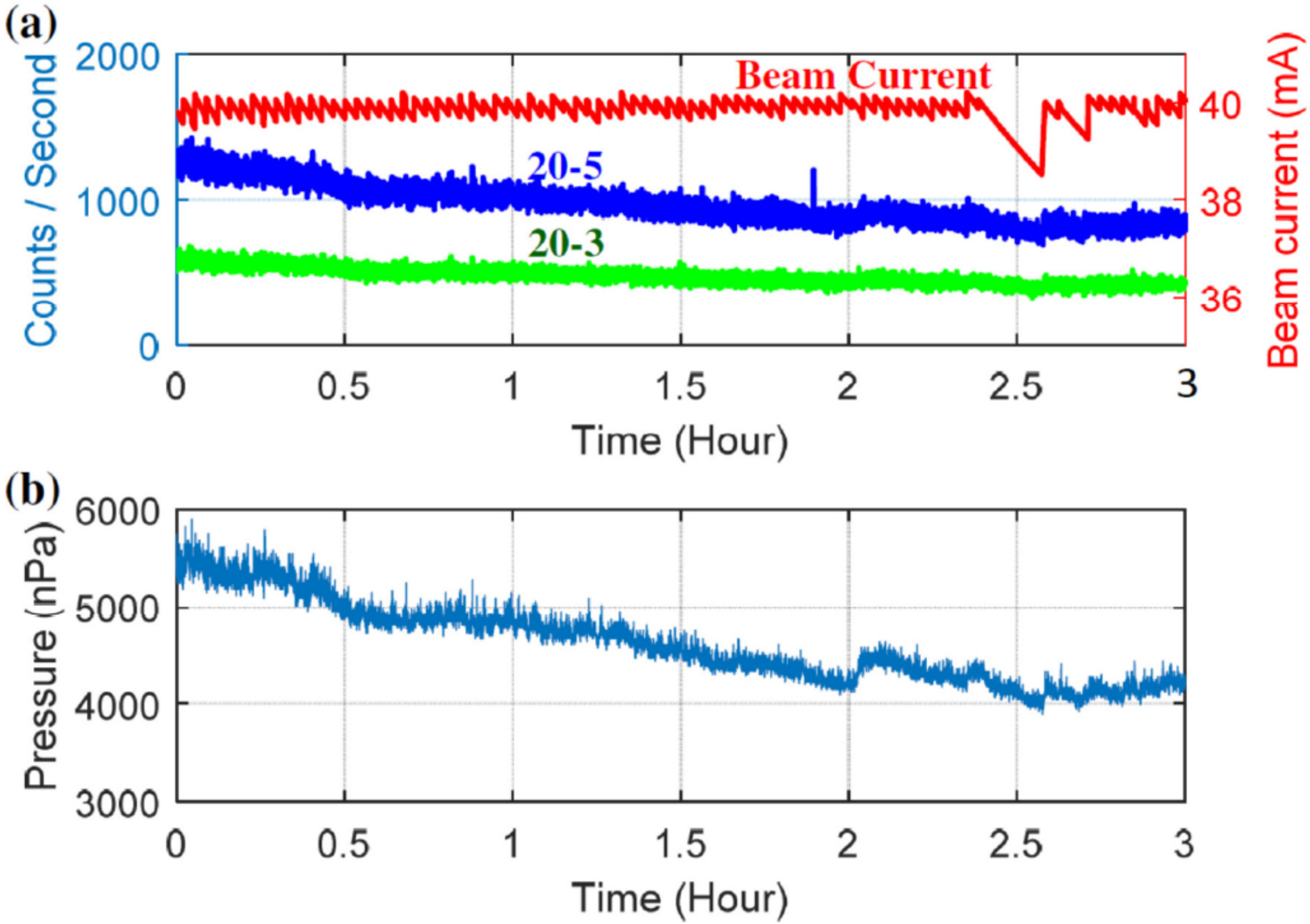
(a)



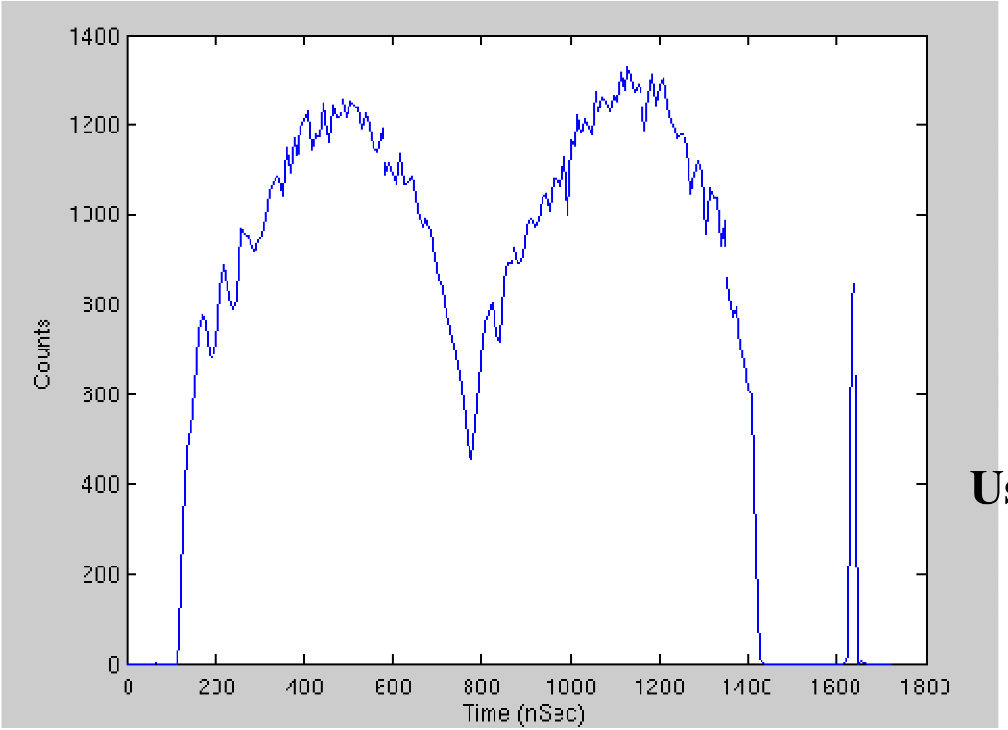
(b) **Gap of IUT 22 installed between cell 10 and 11**



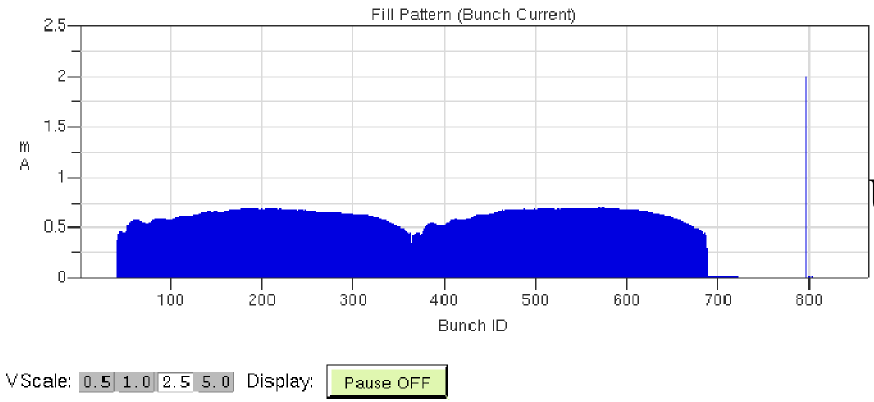
Radiation dose rate vs. Vacuum pressure



Beam loss vs bunch current



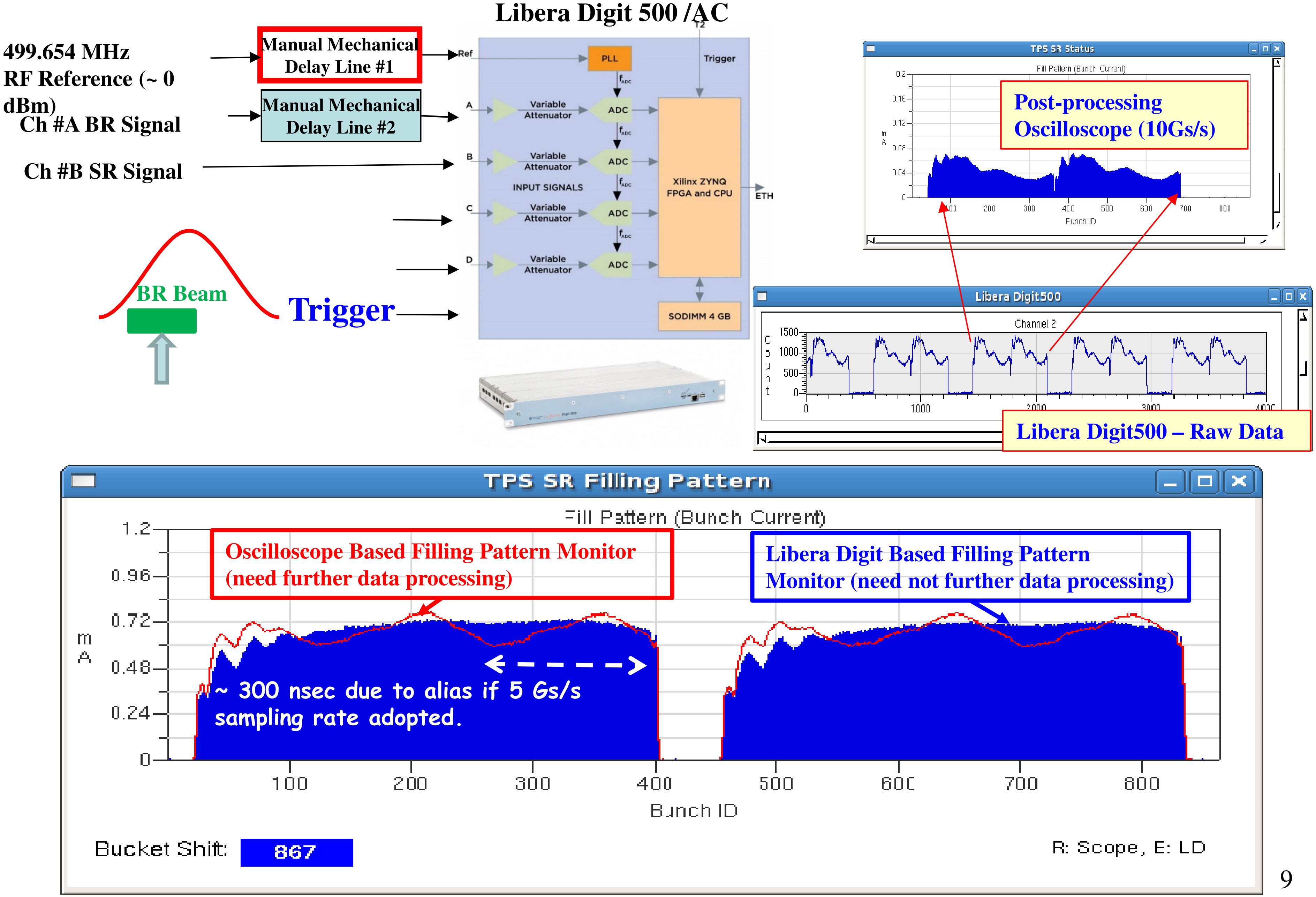
Using Libera BLM.



Using Libera Digit 500.

The resolution of beam loss monitor in the time domain is 8 nsec.

TPS BR/SR filling pattern monitor - Libera Digit500 Option



Polarization time

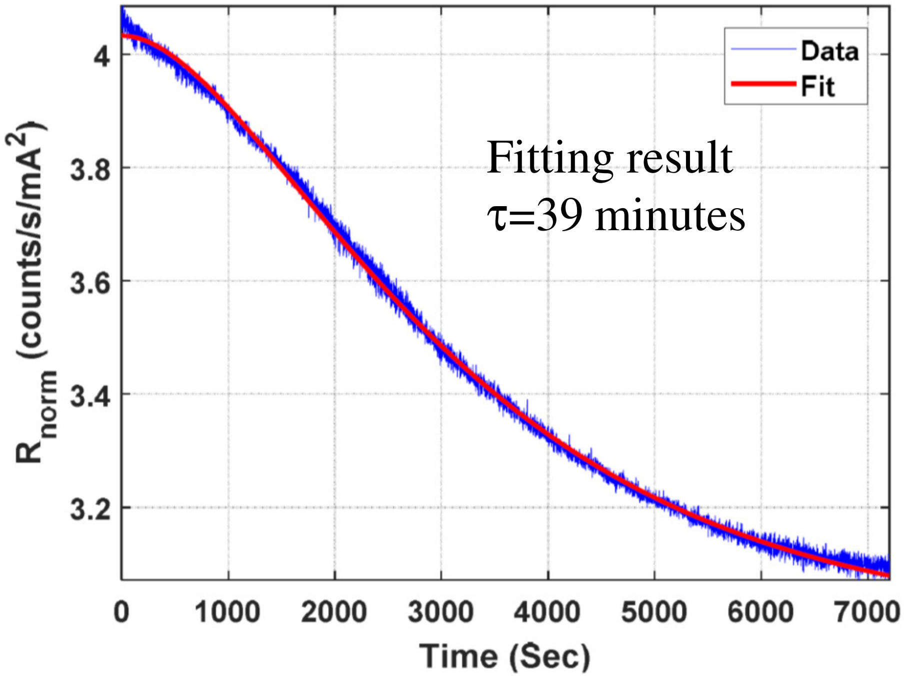
When an unpolarised electron beam is injected into a storage ring with vertical guiding fields, the emission of synchrotron radiation can flip the electron spin with asymmetric transition rates and making the electron spin anti-parallel to the guiding field.

The polarization (P) process can be described by

$$P(t) = P_0 \left(1 - e^{-\frac{t}{\tau}}\right) .$$

For an ideal flat storage ring without field errors, a maximum degree of 92.38% polarization (P_0) can be reached and the polarization time (τ) with identical dipoles is

$$\tau\,[s] = 98.66 \frac{\rho^2\,[m]\,R\,[m]}{E^5\,[\mathrm{GeV}]},$$



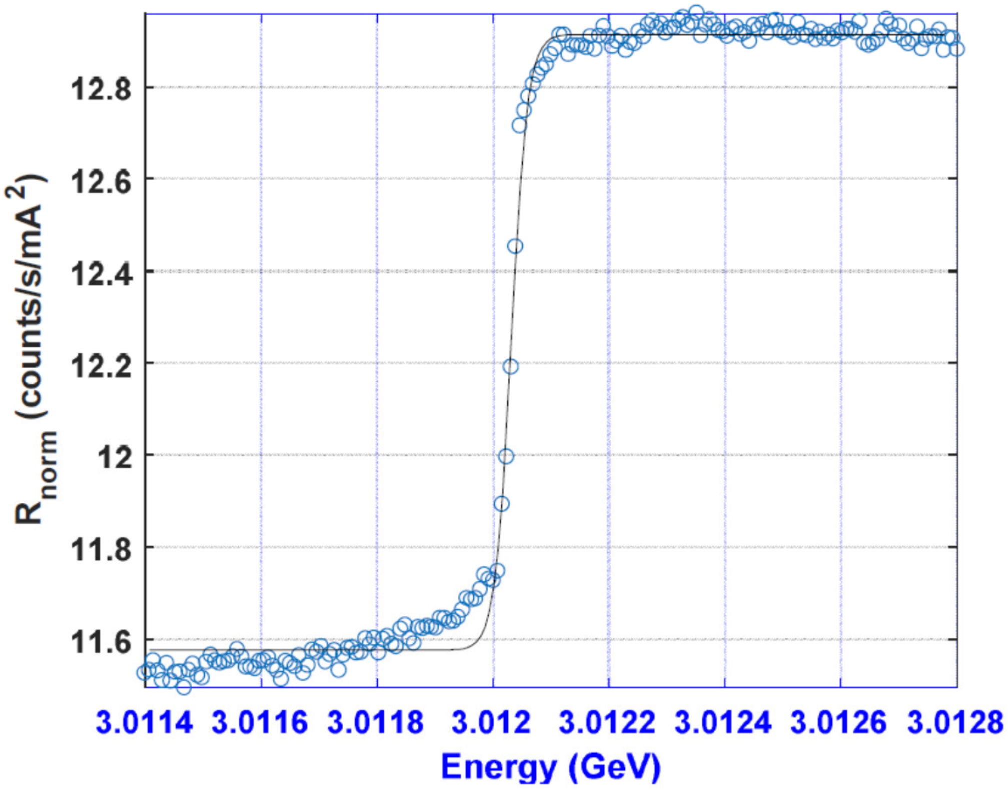
For TPS, the operating energy (E) is 3 GeV, is 8.40 m, R is 82.5 m and the polarization time is around 40 minutes.

$$R_{\mathrm{norm}} = \frac{1}{I^2}\frac{dN}{dt} \propto a + b \times P^2.$$

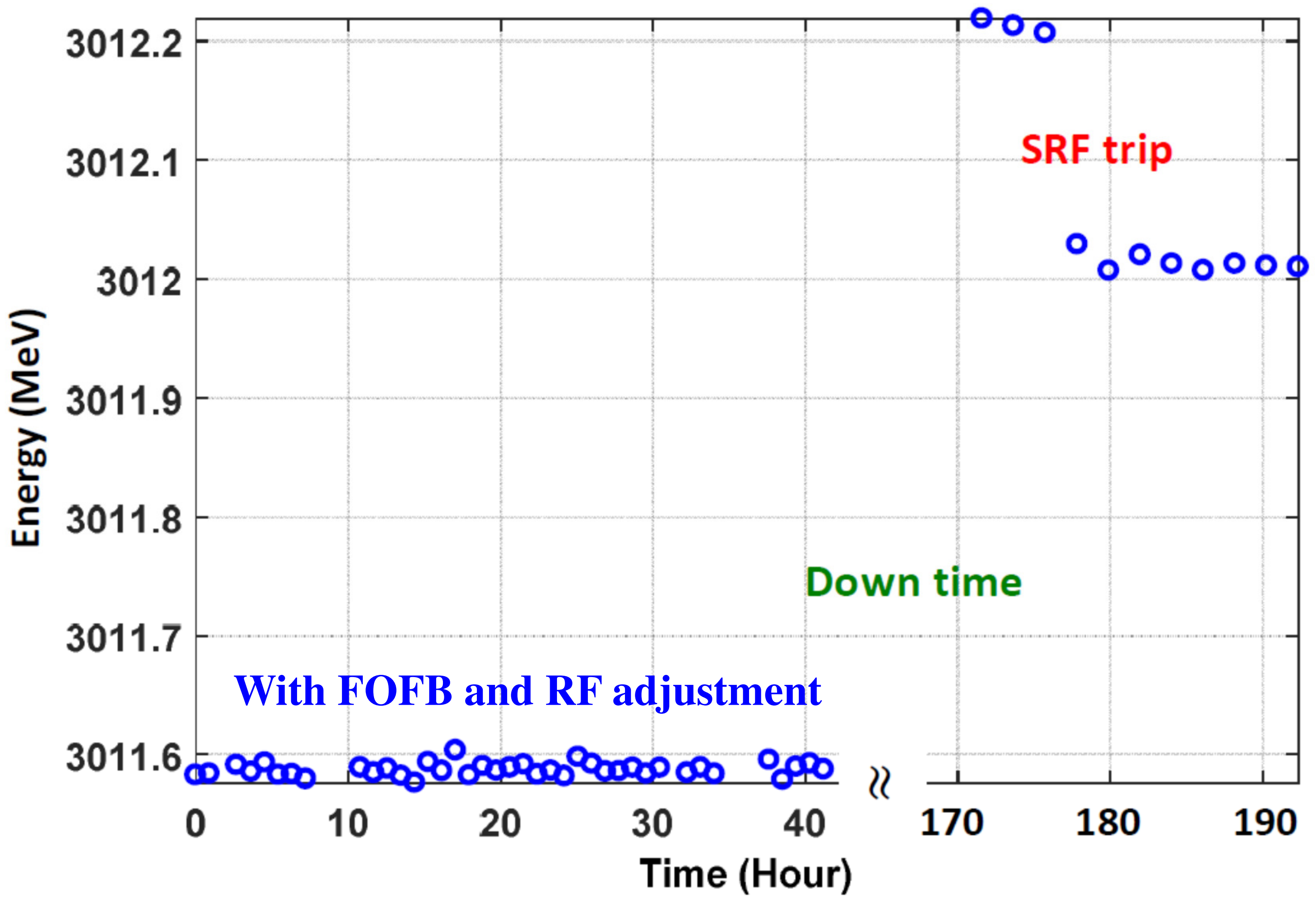
Beam energy

To calibrate the absolute beam energy of the TPS from depolarization, a sinewave is generated by a function generator and amplified before being sent to a vertical strip-line kicker. The normalized beam loss shows 10% steps while crossing the depolarization frequency (f_{dep}). The beam energy E is then

$$E[\mathrm{MeV}] = m_e c^2 \nu_s/\alpha = 440.648626([\nu_s] + f_{\mathrm{dep}}/f_0),$$



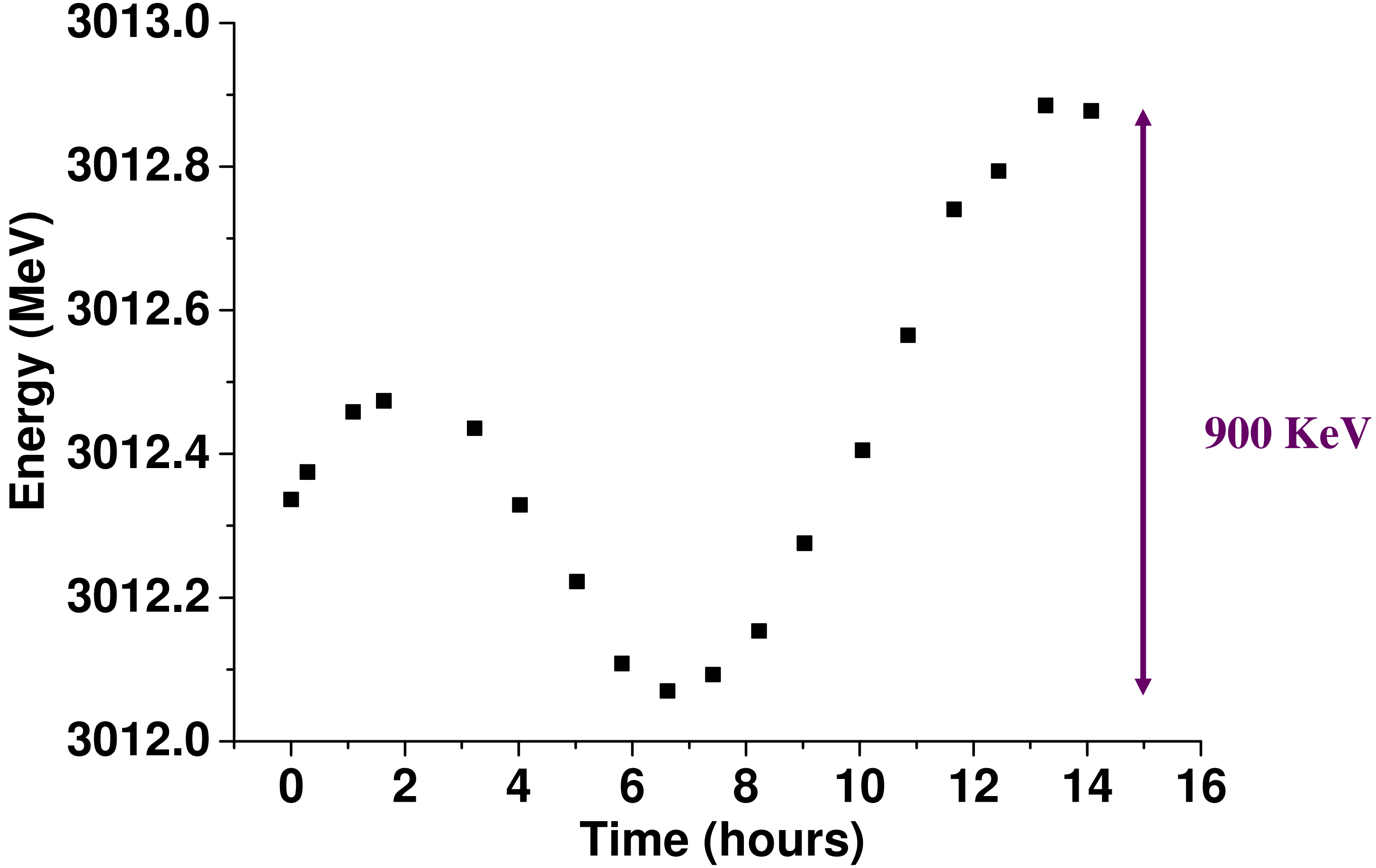
Beam energy variation during routine operation



The beam energy stability measured by resonant spin depolarization is less than 20 keV ($\Delta E/E \sim 7*10^{-5}$) during continuous operation.

The energy variation between beam trip or complete ring fills is in the order of 200 keV or more . This energy variation may come from orbit variations.

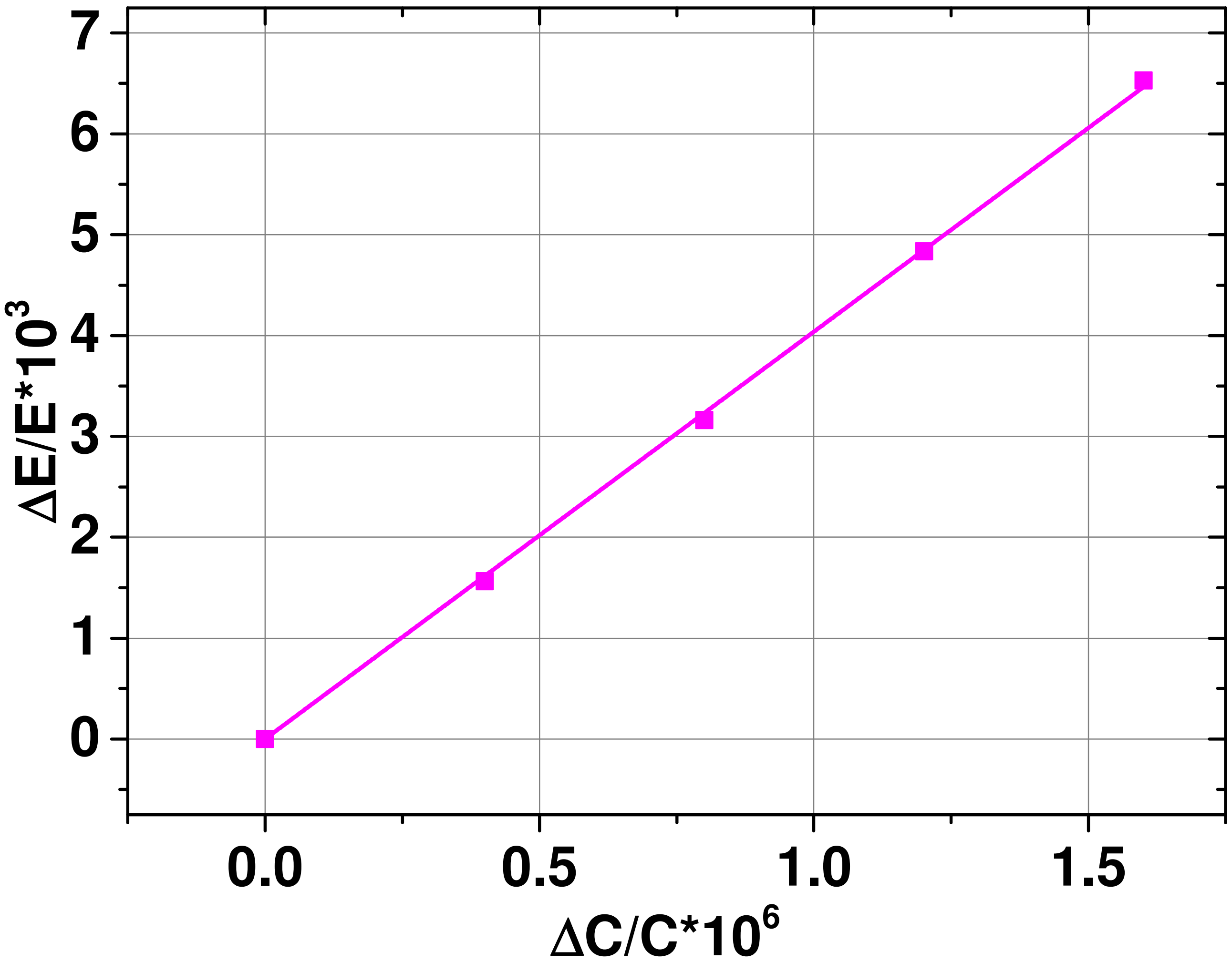
Beam energy variation without feedback



The energy variation without feedback is much higher than with feedback and RF adjustment.

Compaction factor

α_1=2.47*10^{-4}



$$\Delta E/E = \frac{1}{\alpha_1}\Delta C/C$$

Summary

- **To study beam loss mechanisms, radiation-sensing field-effect transistors (RadFETs), dual PIN diode beam loss monitors (BLMs), and scintillation detectors (Libera BLMs) are installed at the Taiwan Photon Source.**
- **High synchrotron radiation areas are located prior to the second bending magnet and straight section because of nearby photon absorbers.**
- **To shield BLMs from synchrotron radiation, 1 mm-thick lead shields are used in this area for both enhancing the sensitivity of the beam loss and reducing the radiation damage to the BLMs.**
- **The beam loss pattern can be easily observed and is quite different when the insertion devices are closed independent of injection or decay period during routine operation.**
- **Spin-polarization time and beam energy can be determined by using scintillation detectors which are installed after the first bending magnet.**
- **The energy stability of the TPS is within 20 keV due to the precise control of the beam orbit by the fast orbit feedback system and radio frequency adjustment.**
- **The beam loss pattern in the time domain can also be detected by Libera BLMs.**

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Thanks for your kind attention.

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