Neutron flux measurement for beam polarization study at FnPB of SNS

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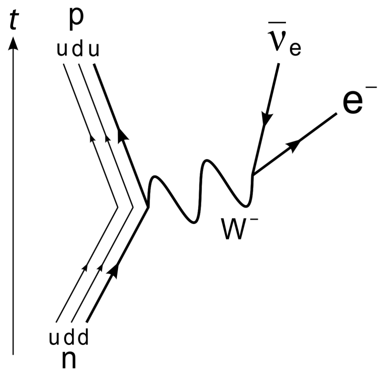
Neutron beta Decay and N_{ab}



$$\frac{dw}{dE_e d\Omega_e d\Omega_\nu} \propto p_e E_e (E_0 - E_e)^2 \left[1 + a\frac{\vec{p}_e \cdot \vec{p}_\nu}{E_e E_\nu} + b\frac{m_e}{E_e} + \langle\vec{\sigma}_n\rangle \cdot \left(A\frac{\vec{p}_e}{E_e} + B\frac{\vec{p}_\nu}{E_\nu} + \cdots\right)\right]$$

Neutrino-Electron-Correlation

$$a = \frac{1 - |\lambda|^2}{1 + 3|\lambda|^2}$$

$$\lambda = \frac{g_A}{g_V}$$

Beta−Asymmetry

$$A = -2\frac{|\lambda|^2 + \mathrm{Re}\,\lambda}{1 + 3|\lambda|^2}$$

Neutron lifetime $\Gamma = \tau_n^{-1} = \frac{2\pi}{\hbar} G_F^2 V_{ud}^2 (1 + 3|\lambda|^2) \int \rho(E_e) dE_e$, Fierz interference term $b = 0$

Current PDG values

$a = -0.1049 \pm 0.0007$

$b = 0.017 \pm 0.020$

Nab Goal:

$\Delta a / a = 0.1\%$

$\Delta b = 3 \times 10^{-3}$

Uncertainty budget

Discussed in this session

This Talk

Experimental Parameter	$(\Delta a/a)_{syst}$
Magnetic Field	$6.0 \cdot 10^{-4}$
Electric Potential Inhomogeneity	$5.5 \cdot 10^{-4}$
Adiabaticity of Proton Motion	$1 \cdot 10^{-4}$
Detector Effects	$7.1 \cdot 10^{-4}$
Electron TOF	small
Residual Gas	$3.8 \cdot 10^{-4}$
TOF in Acceleration Region	$3 \cdot 10^{-4}$
Background/Accidental Coincidences	$< 1 \cdot 10^{-4}$
Neutron Beam	$3.2 \cdot 10^{-4}$
… position	$1.7 \cdot 10^{-4}$
…profile	$2.5 \cdot 10^{-4}$
…Doppler Effect	small
…Unwanted beam polarization	$1 \cdot 10^{-4}$
Total	$1.2 \cdot 10^{-3}$

Effect of Neutron Polarization

$$\frac{dw}{dE_e d\Omega_e d\Omega_\nu} \propto p_e E_e (E_0 - E_e)^2 \left[1 + a\frac{\vec{p}_e \cdot \vec{p}_\nu}{E_e E_\nu} + b\frac{m_e}{E_e} + \langle\vec{\sigma}_n\rangle \cdot \left(A\frac{\vec{p}_e}{E_e} + B\frac{\vec{p}_\nu}{E_\nu} + \cdots\right)\right]$$

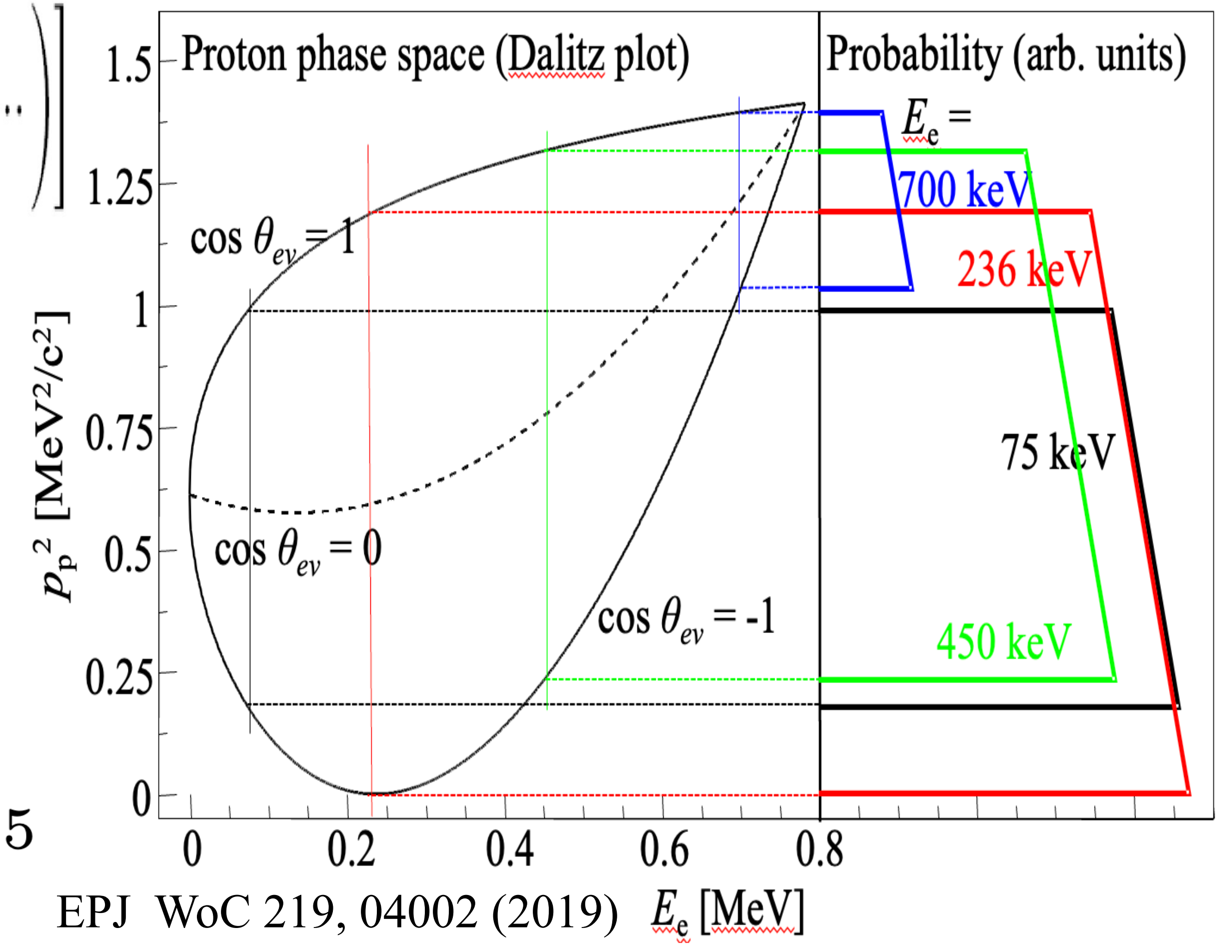
For Unpolarized Target

$$d\Gamma^3 \propto 1 + a \cdot \frac{|\overrightarrow{p_e}||\overrightarrow{p_\nu}|}{E_e E_\nu} cos(\theta_{e\nu}) + b \cdot \frac{m_e}{E_e}$$

If net polarization in the beam

$$|\langle\sigma_n\rangle|(A \cdot \beta_e \langle\cos\theta_e\rangle + B\langle\cos\theta_e\rangle \cdot \cos\theta_{e\nu})$$

$$\frac{\Delta a}{a} \sim 10^{-4} \qquad |\langle\sigma_n\rangle| < 2 \times 10^{-5}$$



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Neutron beam polarization measurement

The capture Cross section for reaction $^3He + n \rightarrow p + {}^3H$ highly spin dependent.
It is minimum when the spins are aligned and maximum with spins anti-aligned.

Transmission of Neutrons:

For unpolarized He cell. $T_0 = Ne^{-\kappa} \quad \kappa = nl\sigma_0 \frac{\lambda}{\lambda_0}$

For polarized cell. aligned spin $T_{up} = (1 - P_n \tanh(\kappa P_{He}))e^{-\kappa}\cosh(\kappa P_{He})$

For polarized cell. opposite spin $T_{dn} = (1 + P_n \tanh(\kappa P_{He}))e^{-\kappa}\cosh(\kappa P_{He})$

Assuming perfect spin flip of He,

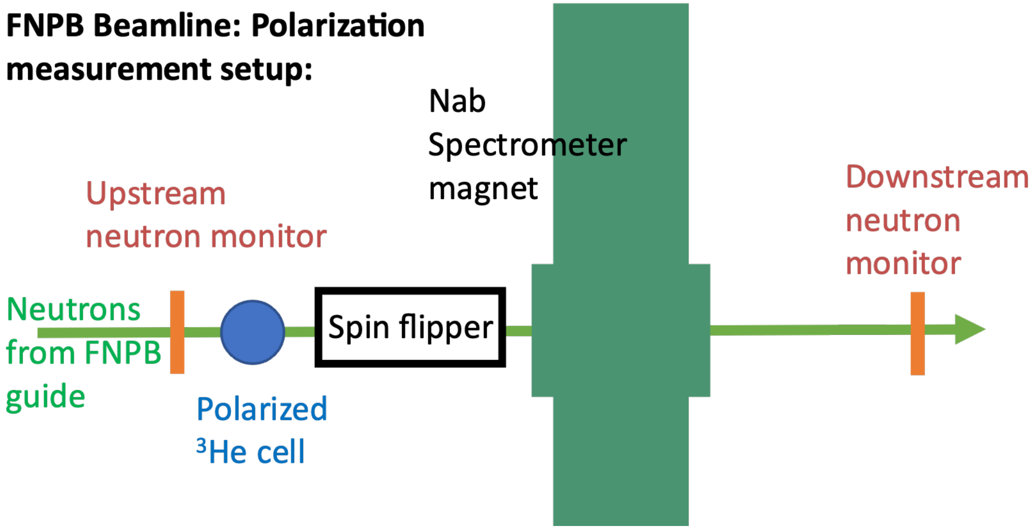
$$P_n = \frac{R_{dn} - R_{up}}{\sqrt{(R_{up} + R_{dn})^2 - 4}} \qquad R_{up} = \frac{T_{up}}{T_0}, R_{dn} = \frac{T_{dn}}{T_0}$$

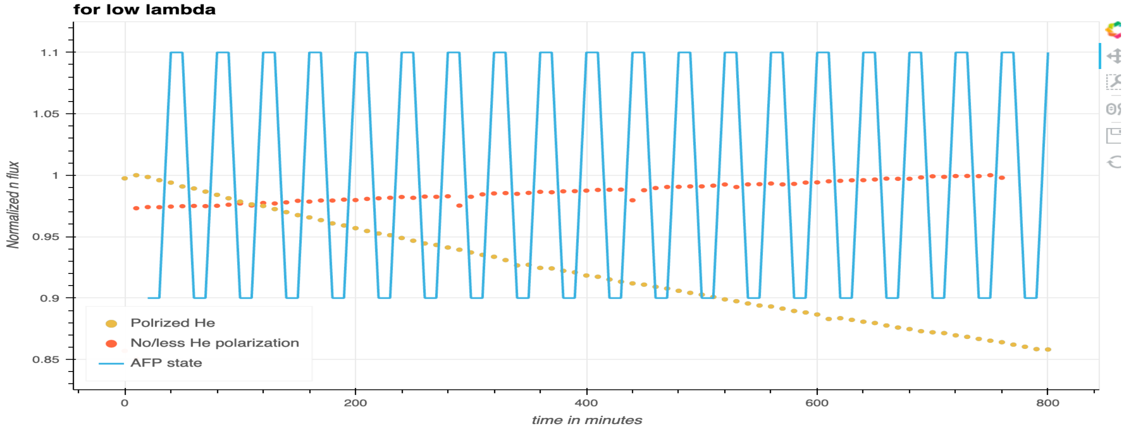
Although very efficient, Polarization of He is lost when spin is flipped

$$P_n = \frac{R_{down} - R_{up}}{\sqrt{(R_{up} + R_{down})^2 - 4}} + \frac{\kappa P_{He}}{2}\bar{\epsilon}_{AFP} + \text{higher orders}$$

Neutron beam polarization measurement

- Beam flux measured in the upstream monitor for normalization.
- The neutron beam passes through the polarized 3He cell.
- Spin flipper is not used in this setup.
- Beam intensity is measured in the downstream monitor.
- During experiment the He spin is flipped
- Data from all detectors is collected in the
- Multi-channel voltage ADC.





Beam Flux measurement

Upstream Monitor

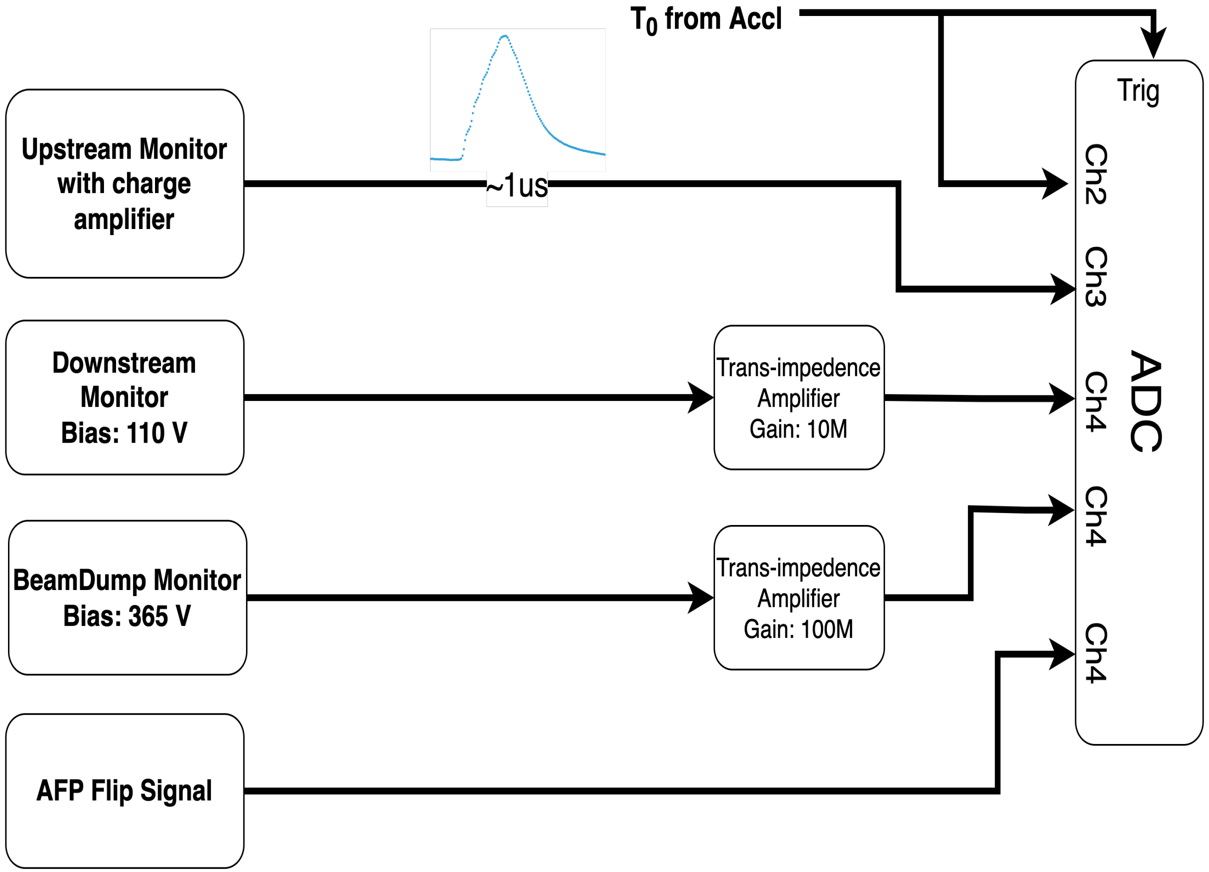
- Counting type detector with $^{14}N + CF_4$ gas mixture
- Able to detect individual neutrons.
- Used with preamp to get single neutron event.
- Produces narrow signals. ~500ns width

Downstream Monitor:

- Thick Monitor filled with ^{3}He.
- Does not detect individual neutrons and needs high flux.
- Produces current proportional to neutron flux.

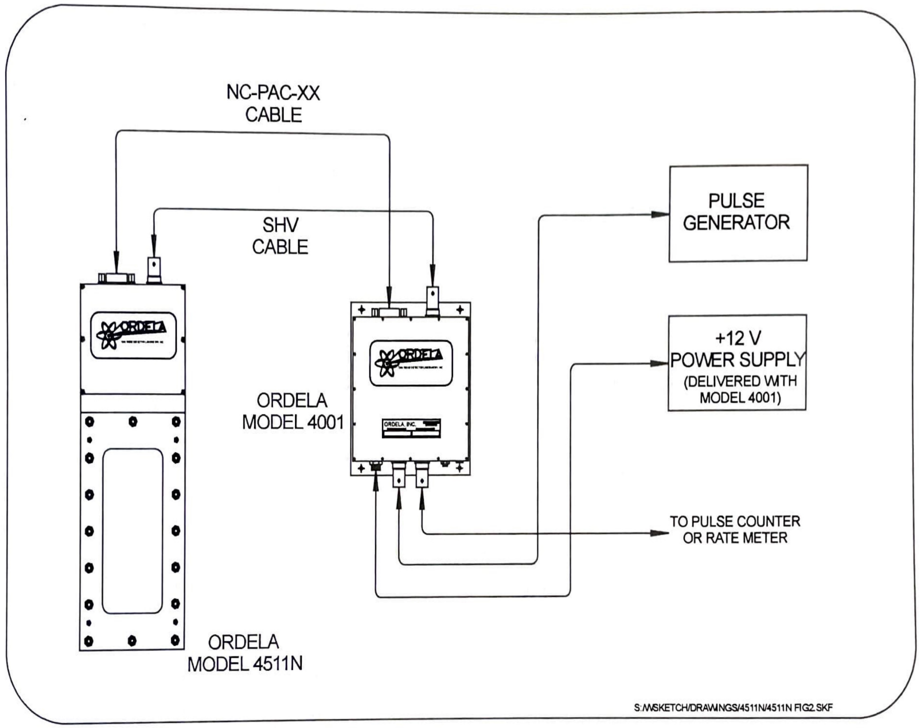
DAQ:

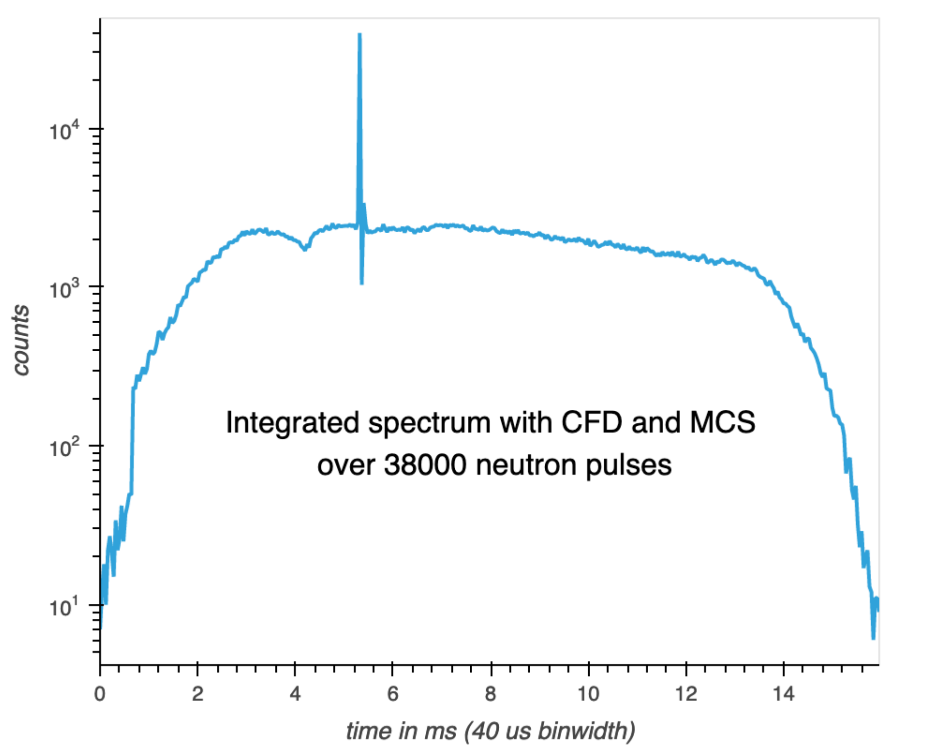
- Our DAQ contains voltage ADC, with 48 channels.
- It works in triggered mode
- Triggered by signal form SNS at 60Hz.
- For each trigger, data is sampled at 400us, for ~16ms, i.e, 40 time bins



Beam Flux Measurement

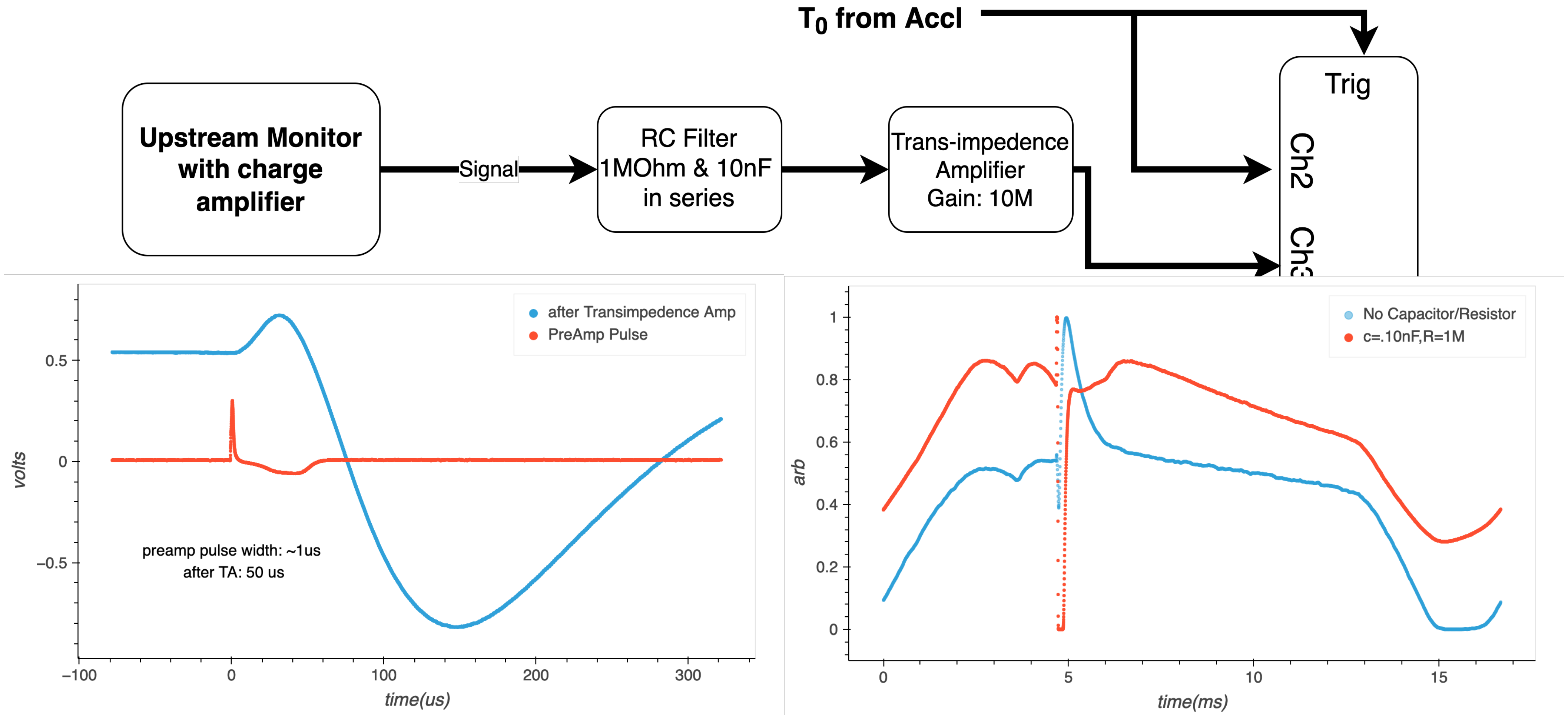
Can't directly incorporate, current upstream monitor in DAQ





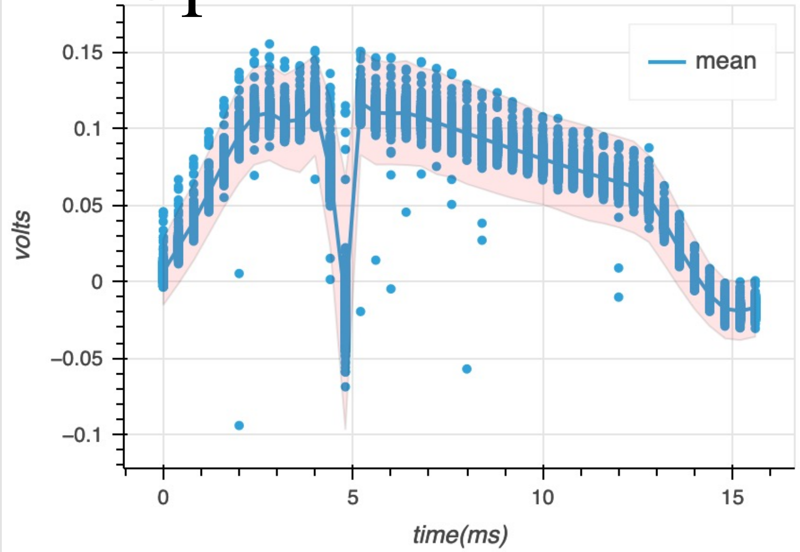
- dynamic range
- Large integration time

Beam Flux Measurement

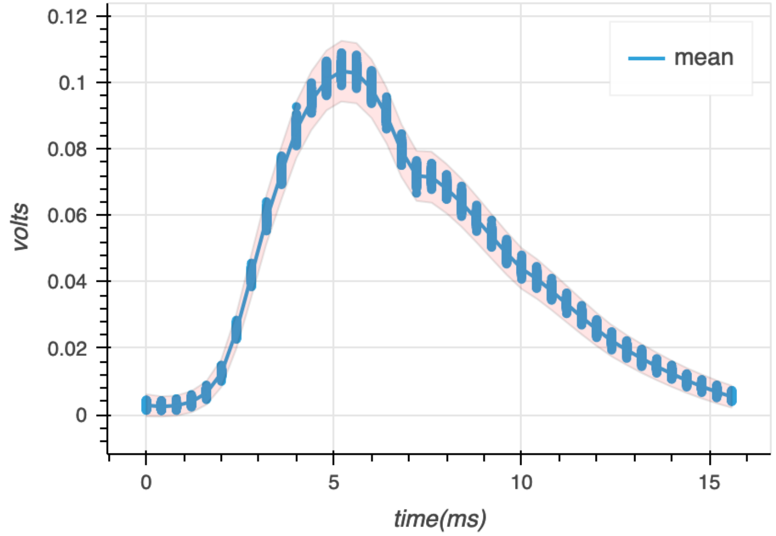


Beam Flux Measurement

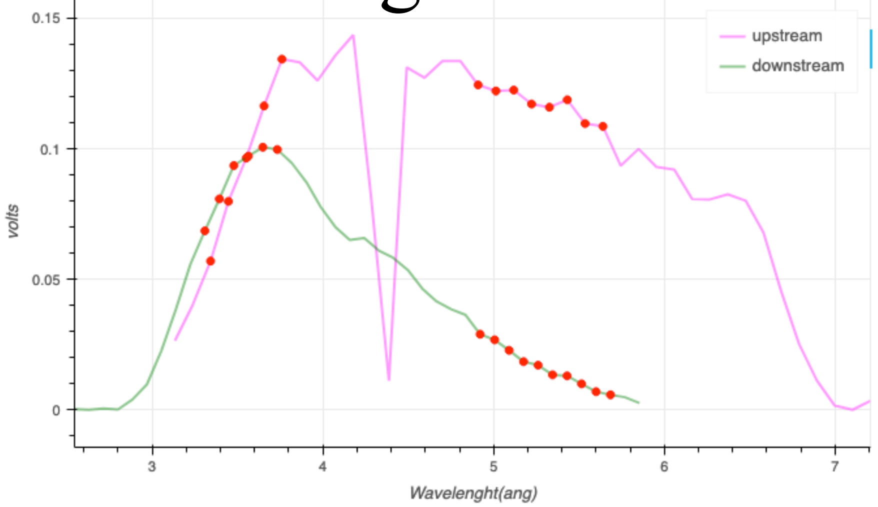
Upstream Monitor



Downstream Monitor



Wavelength calibrated



Summary & Outlook

- Different types of Upstream and Downstream Monitors.
- Used TA to convert pulses into the instantaneous current.
- Fluctuations in upstream monitor is higher than downstream.
- Used the setup to do the beam polarization measurement.

- Increase the efficiency of upstream monitor.
- Change the DAQ system/downstream monitor.

Thanks!!

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The Nab Collaboration

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