Phase Step Method for Friction Force Measurement in Filter Stochastic Cooling

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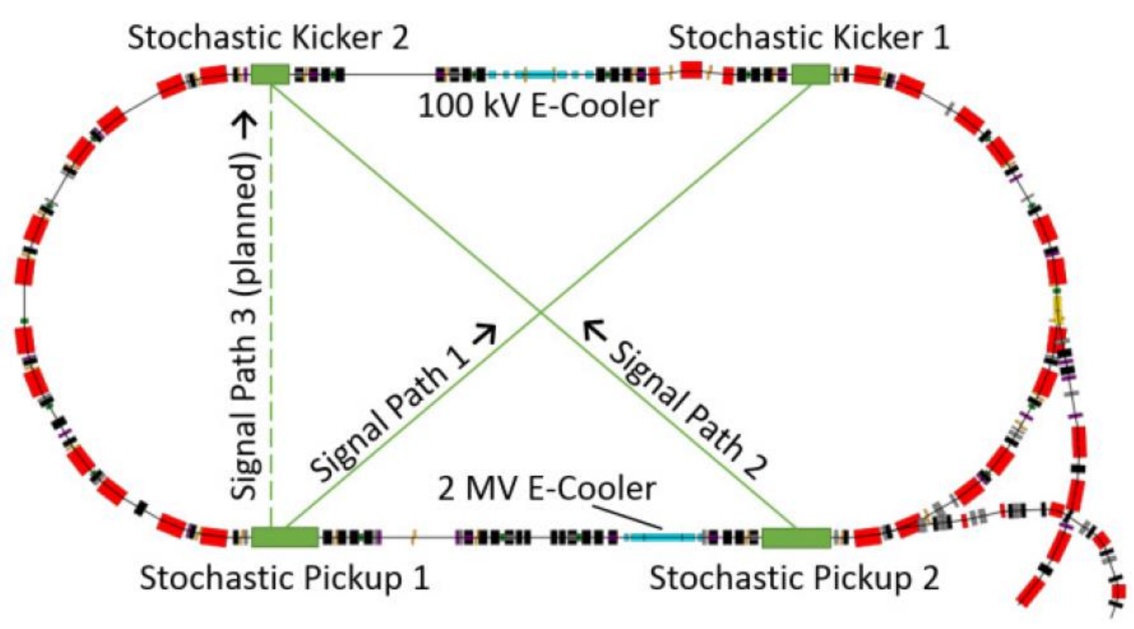
Voltage step method for friction force measurement in electron cooling is well known. The similar method for friction force measurement in longitudinal stochastic cooling with comb filter is provided. First test of the method during the run at COSY has been implemented.

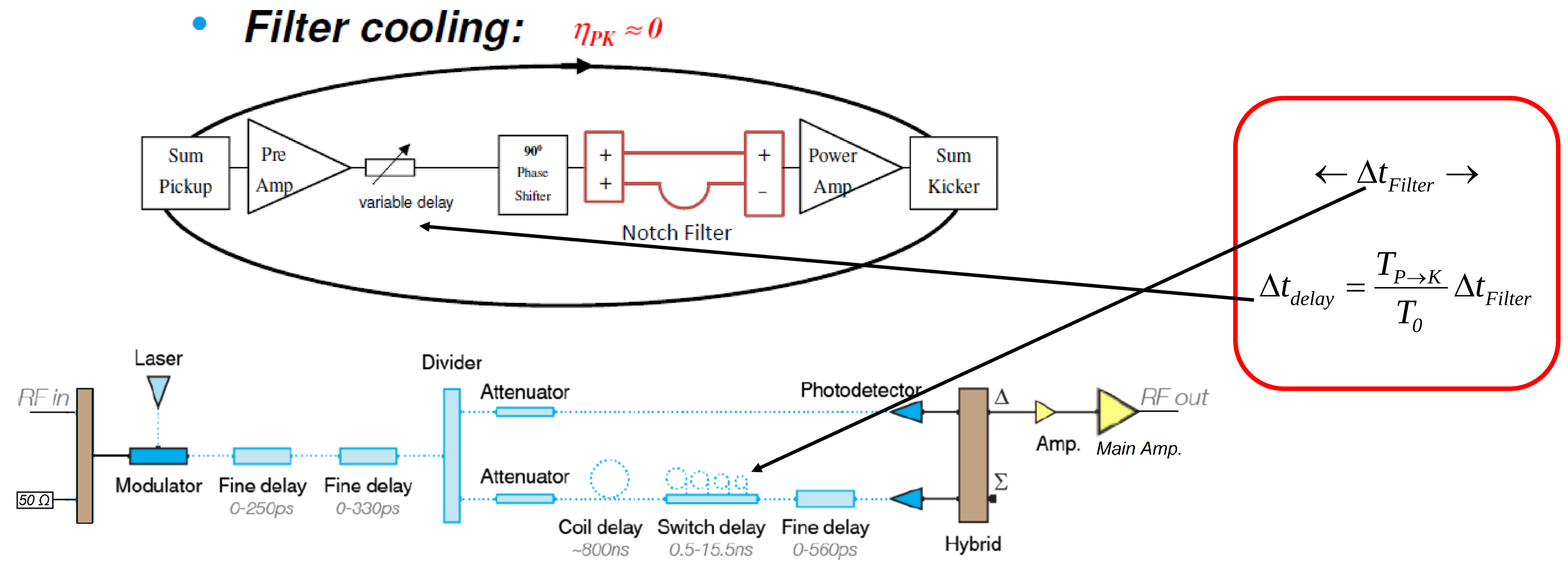
COSY Stochastic Cooling

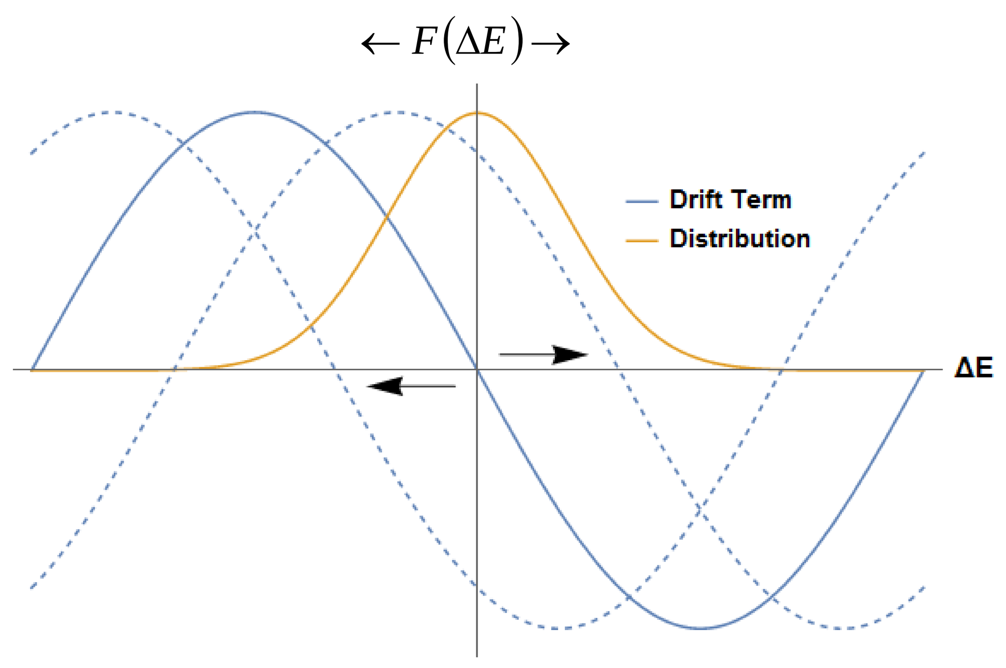


Parameters	
Circumference, m	*184*
Ions	p^+
Energy, Gev/u	*2,285*
η	*-0,1*
Intensity	$\sim 3\cdot 10^9$
$\Delta p/p_0$	$\sim 3\cdot 10^{-4}$
Bandwidth, GHz	*2 – 4*
Output power, W	*400*

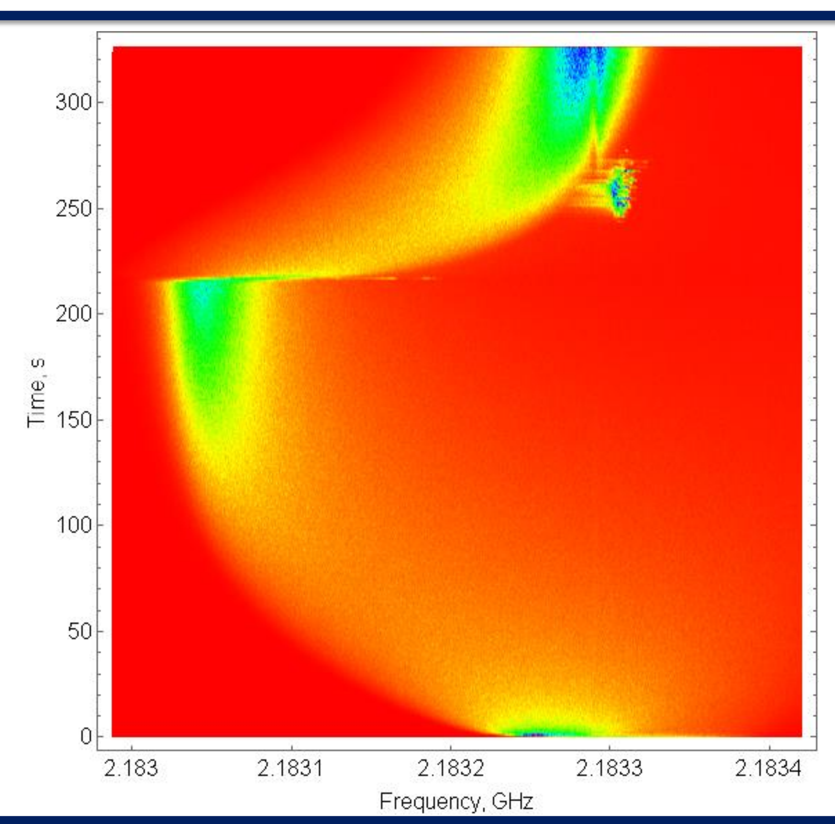
Procedure

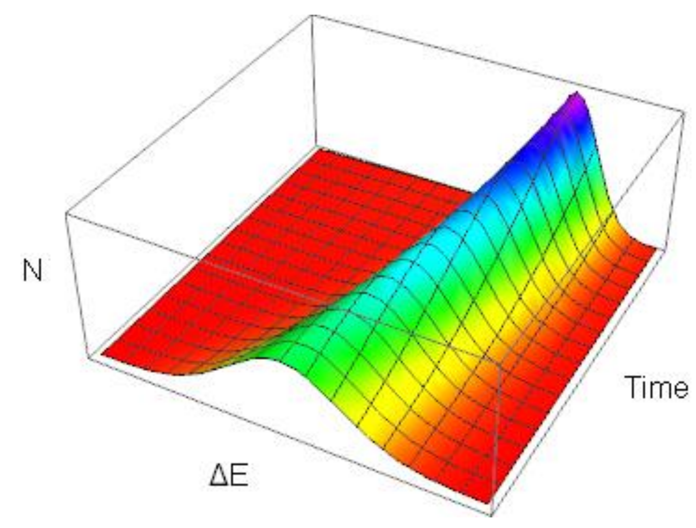
- ***Filter cooling:*** $\eta_{PK} \approx 0$



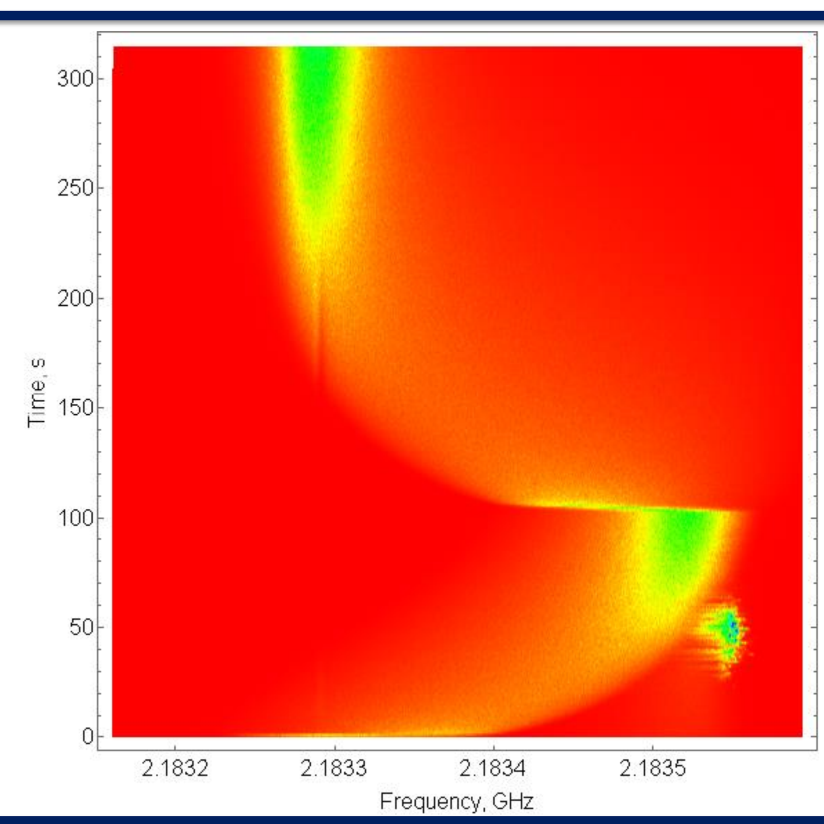


Measurements



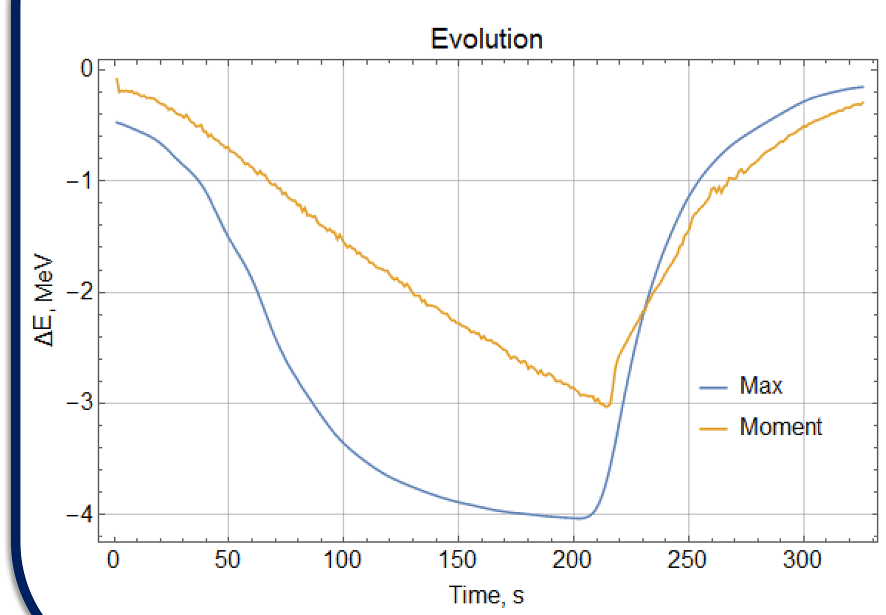


$f_0 = 1.559493 MHz \qquad n_h = 1400$



Processing

Measurement 1



FPE: $$\frac{\partial \Psi(E,t)}{\partial t} + \frac{\partial}{\partial E}\left(F(E)\Psi(E,t)\right) - \frac{\partial}{\partial E}\left\{\left(D_a + D_b(E)\Psi(E,t)\right)\frac{\partial \Psi(E,t)}{\partial E}\right\} = 0$$

By Distribution Moment

$$\frac{dM}{dt} = \int E\left[-\frac{\partial}{\partial E}\left(F(E)\Psi(E,t)\right) + \frac{\partial}{\partial E}\left\{\left(D_a + D_b(E)\Psi(E,t)\right)\frac{\partial \Psi(E,t)}{\partial E}\right\}\right]dE$$

$$\int -E\frac{\partial}{\partial E}\left(F(E)\Psi(E,t)\right)dE = \int F(E)\Psi(E,t)dE = \langle F\rangle_\Psi$$

$$\int E\frac{\partial}{\partial E}\left\{\left(D_a + D_b(E)\Psi(E,t)\right)\frac{\partial \Psi(E,t)}{\partial E}\right\}dE = \left\langle\frac{\partial D_a}{\partial E}\right\rangle_\Psi + \left\langle\frac{\partial D_b}{\partial E}\right\rangle_{\Psi^2} \approx 0$$

$$\frac{dM}{dt} = \langle F\rangle_\Psi \xrightarrow{\Psi\to\delta} F(M)$$

By Distribution Maximum

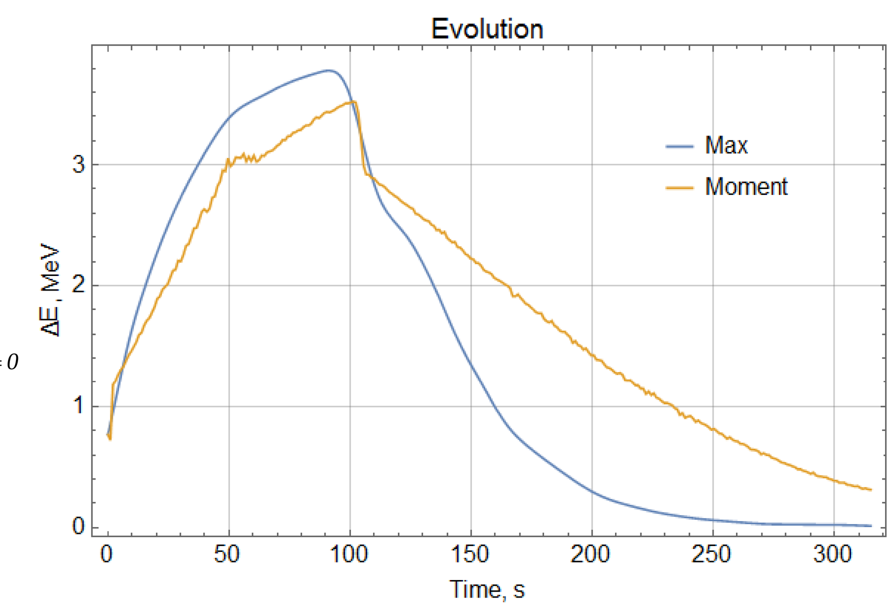
$$\Psi(E_{Max},t) \Leftrightarrow \left.\frac{\partial \Psi(E,t)}{\partial E}\right|_{E_{Max}} = 0$$

$$\frac{\partial \Psi(E_m,t)}{\partial t} + \frac{\partial}{\partial E}\left(F(E_m)\Psi(E_m,t)\right) - \cancel{\frac{\partial}{\partial E}\left\{\left(D(E_m)\Psi(E_m,t)\right)\frac{\partial \Psi(E_m,t)}{\partial E}\right\}} = 0$$

$$\frac{\partial \Psi(E_m,t)}{\partial t} + \frac{\partial F(E_m)}{\partial E}\Psi(E_m,t) + F(E_m)\frac{\partial \Psi(E_m,t)}{\partial E} = 0$$

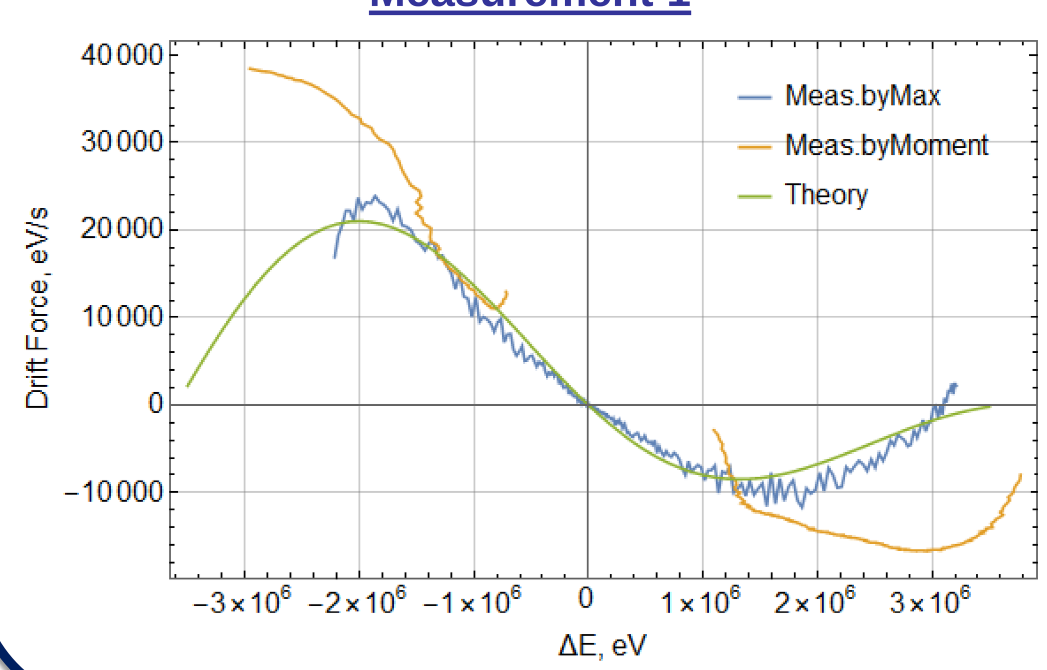
$$F(Eq - E) = -\int_E^{Eq}\frac{1}{\Psi(E_m,t)}\frac{\partial \Psi(E_m,t)}{\partial t}dE_m$$

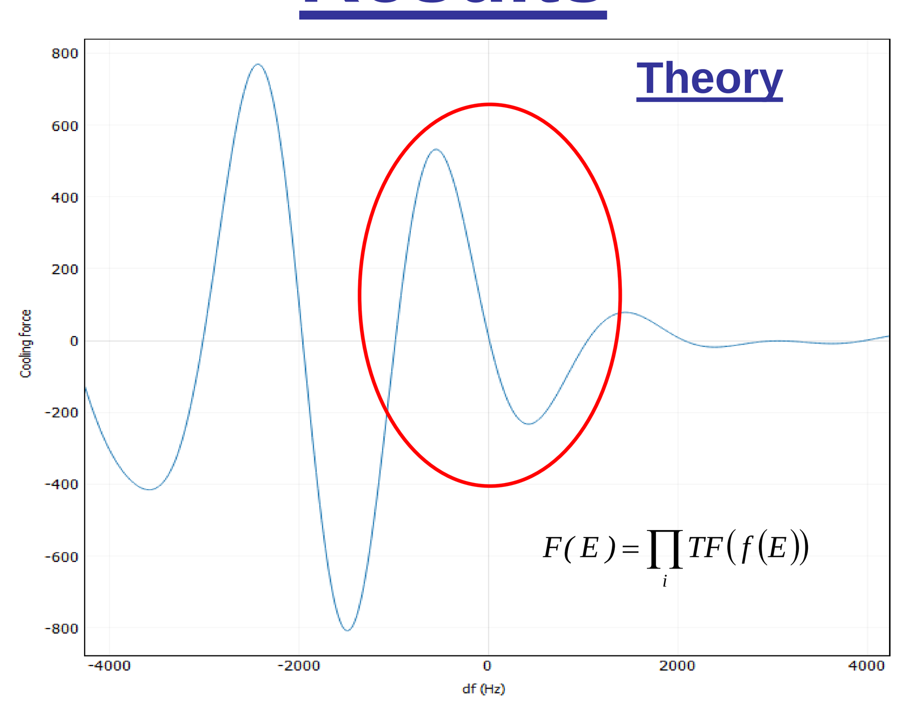
Measurement 2



Results

Measurement 1





Measurement 2