Towards an RF Wien-Filter for EDM Experiments at COSY

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Abstract

The JEDI Collaboration (**J**ülich **E**lectric **D**ipole Moment **I**nvestigations) is developing tools for the measurement of permanent **E**lectric **D**ipole **M**oments (EDMs) of charged, light hadrons in storage rings. The Standard Model predicts nonbservably small values for the EDM. In contrast, a non-vanishing EDM could be detected by measuring an induced tiny build-up of vertical polarization in a beforehand horizontally polarized beam. This technique requires a spin tune modulation by an RF Dipole without any excitation the beam itself.

In the course of 2014, a prototype RF ExB-Dipole has been successfully commissioned and tested. The force of a radial magnetic field is canceled out by a vertical electric one. In this configuration, the dipole fields form a Wien-Filter that directly rotates the particles' polarization vector. We verified that the device can be used to continuously flip the vertical polarization of a 970 MeV/c deuteron beam without exciting any coherent beam oscillations. For a first EDM Experiment, the RF ExB-Dipole in Wien-Filter Mode is going to be rotated by 90° around the beam axis and will be used for systematic investigations of sources for false EDM signals.

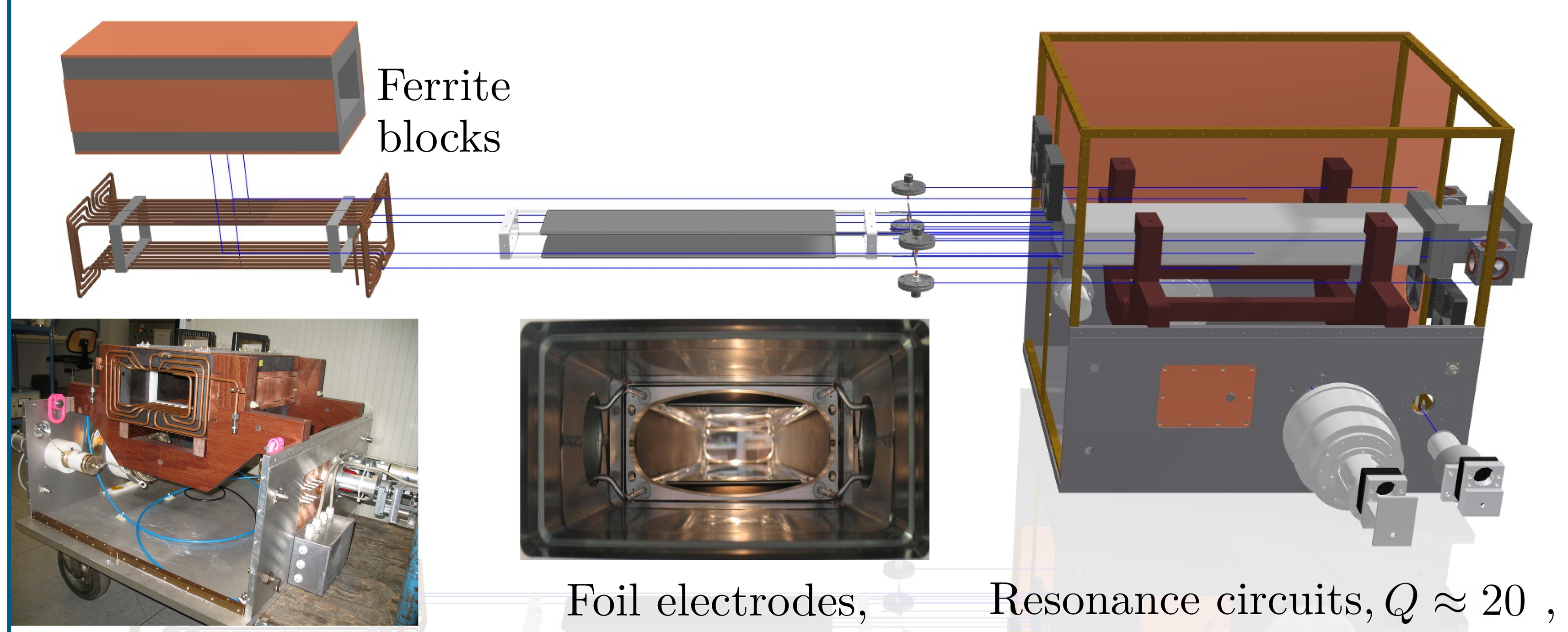
RF ExB Prototype

RF B Dipole $\int \hat{B}_x \, \mathrm{d}z = 0.175\,\mathrm{T\,mm}$

RF E Dipole $\int \hat{E}_y \, \mathrm{d}z = 24.1\,\mathrm{kV}$

Shielding Box ceramic beam chamber

Ferrite blocks

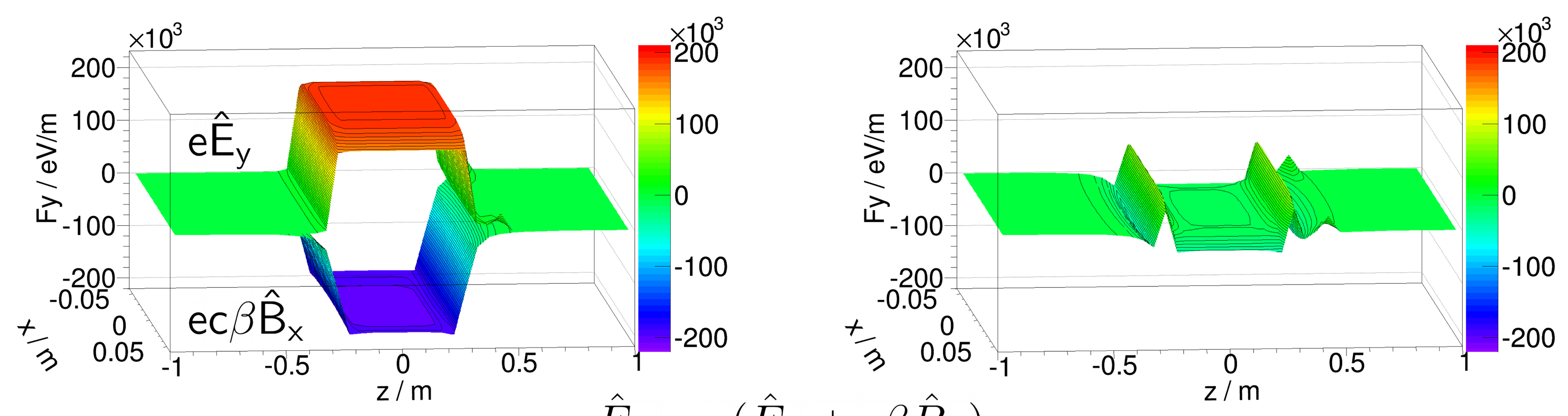


Coil, 8 windings
Length 560 mm
$\hat{I}_{\max} = 5\,\mathrm{A}$

Foil electrodes,
50 µm stainless steel
Distance 54 mm
Length 580 mm
$\hat{U}_{\max} = 2\,\mathrm{kV}$

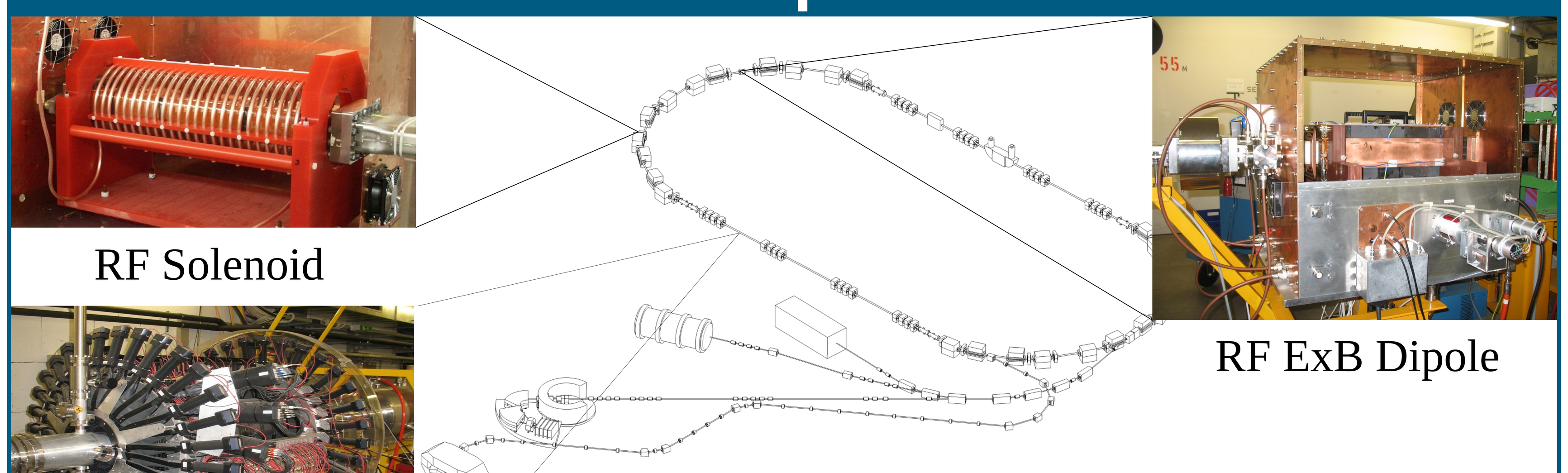
Resonance circuits, $Q \approx 20$,
adjustable, matched to 50 Ω
$\Delta f_{\mathrm{RF}} = 630\,\mathrm{kHz} - 1170\,\mathrm{kHz}$

Lorentz Force Compensation



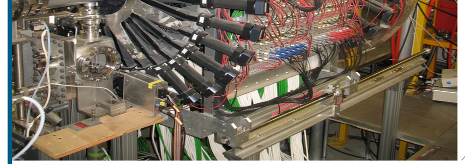
$$\hat{F}_y = e(\hat{E}_y + c\beta\hat{B}_x)$$

Beam Setup at COSY

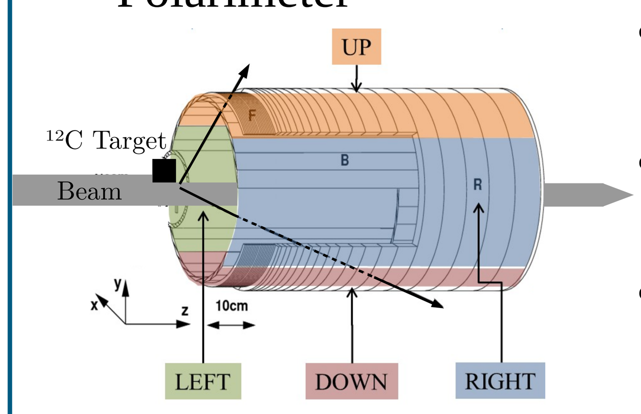


RF Solenoid

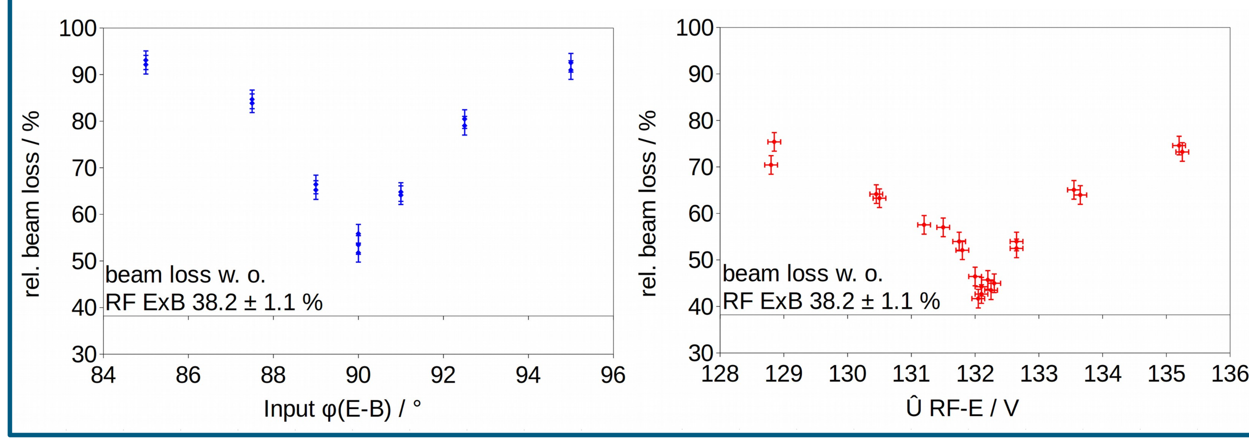
RF ExB Dipole



Polarimeter

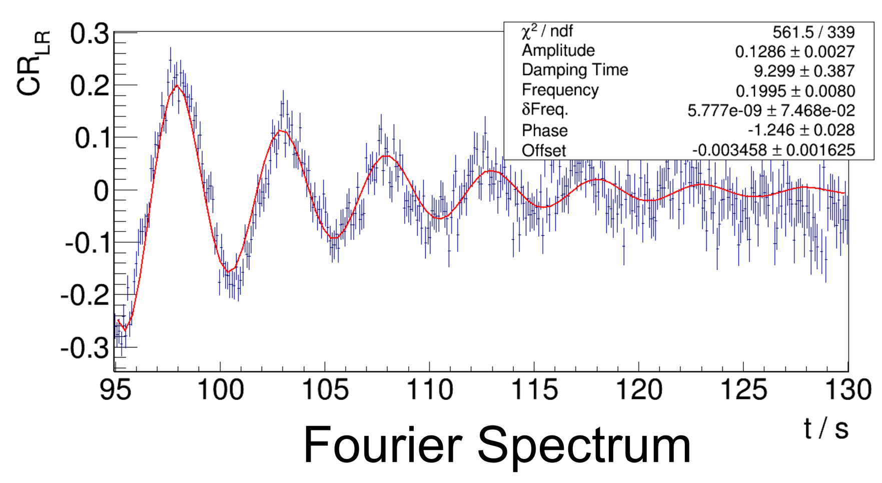


- $\vec{\mathrm{d}}$ at $970\,\mathrm{MeV/c} \Rightarrow f_{\mathrm{rev}} = 750\,\mathrm{kHz}$
  $G = -0.142 \Rightarrow \gamma G = -0.161 \Rightarrow f_{\mathrm{spin}} = 121\,\mathrm{kHz}$
  harmonics at $f_{+1} = 630\,\mathrm{kHz}$ and $f_{-1} = 871\,\mathrm{kHz}$
- Aperture defined by polarimeter target, excited particles extracted from beam
- Lorentz Force cancellation when operating RF device at minimum beam loss
- Max. sensitivity: Adjust optics so that betatron sideband coincides with $f_{\mathrm{RF}} \stackrel{!}{=} f_{-1}$
- Slow extraction of beam onto target ⇒ long observation time

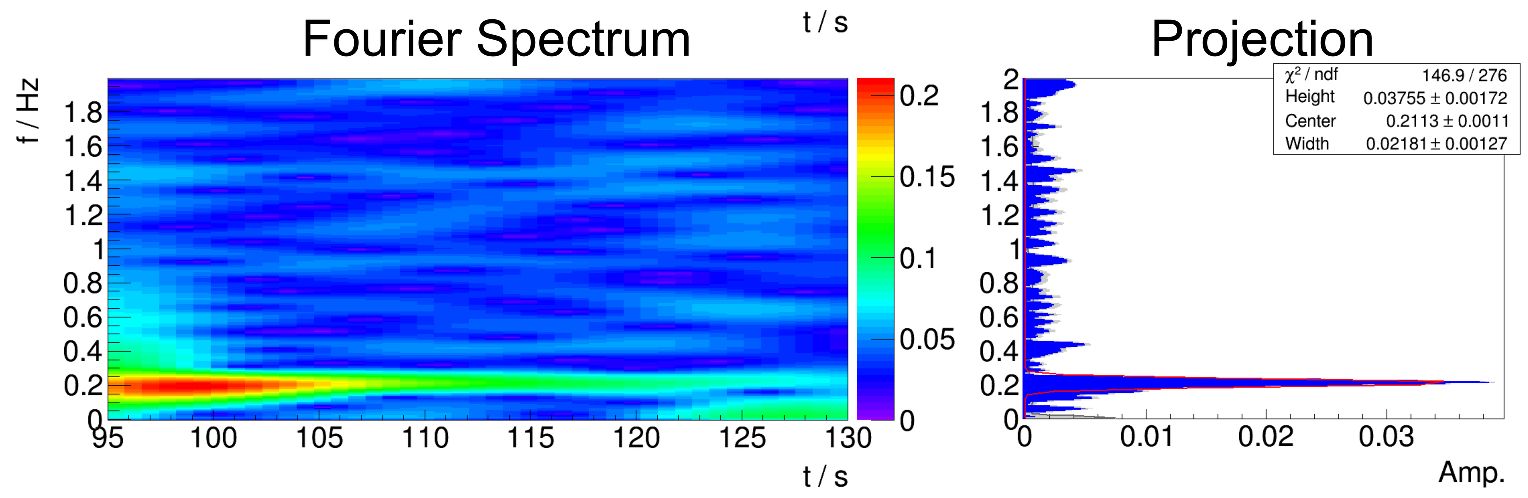


Beam based amplitude and phase matching at $f_{\mathrm{RF}} = f_{q_y} = 871\,\mathrm{kHz}$ and fixed RF B current, $\hat{I} = 233\,\mathrm{mA}$

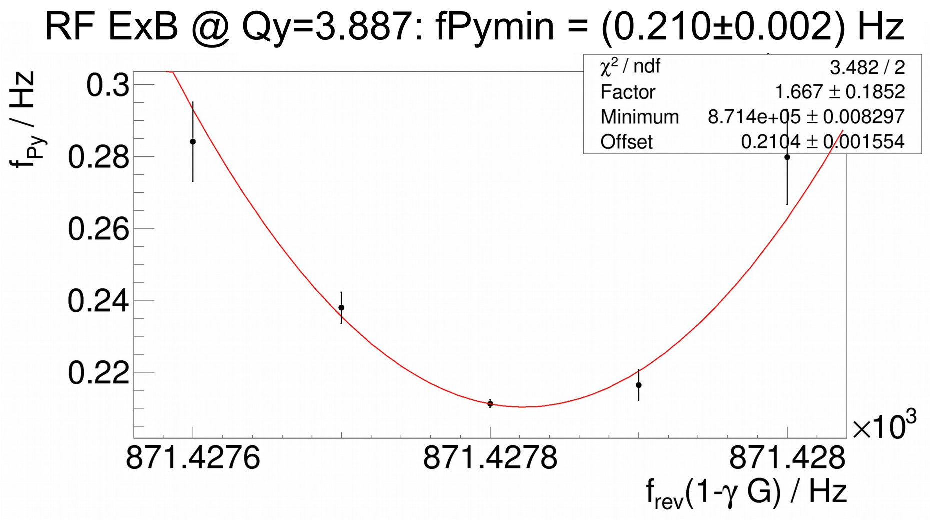
RF Driven Spin Resonance



Vertical polarization oscillation at continuous RF ExB operation on resonance for 40 s. The Fourier Spectrum gives a frequency of $f_{P_y} = (0.211 \pm 0.001)\,\mathrm{Hz}$



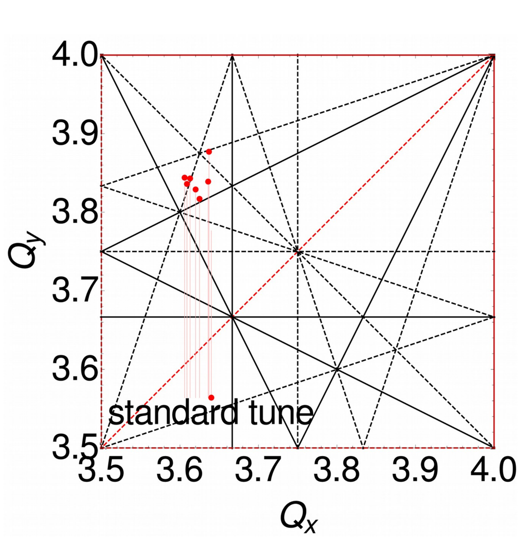
- Vertical Polarization ⇒ left-right asymmetries in $^{12}\mathrm{C}(\vec{\mathrm{d}},\mathrm{d})$
- Localized radial magnetic RF field gives tiny spin kick each turn
- Only RF in phase with spin precession leads to accumulation of kicks

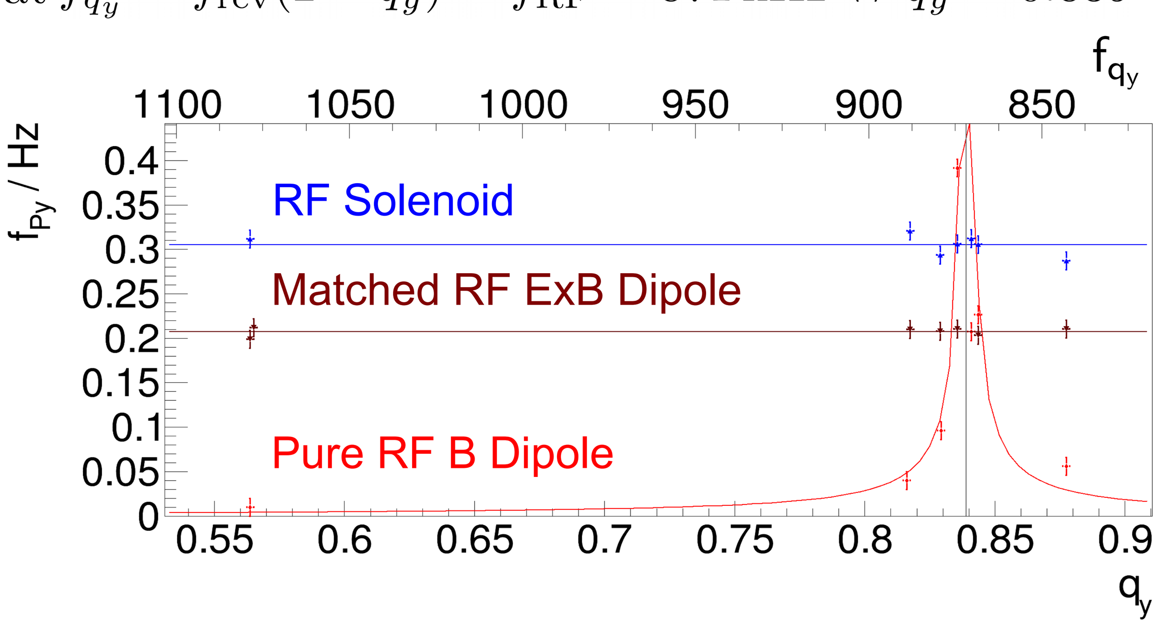


- Exactly on resonance:
- Oscillation around zero, corresponds to average polarization
- Oscillation frequency minimized
- Directly proportional to resonance strength: $\varepsilon = \frac{f_{P_{y\min}}}{f_{\mathrm{rev}}}$

Resonance Strength vs. Betatron Tune

- Further contributions to resonance strength due to interference from coherent beam motion
- Scan of the spin resonance strength at betatron sidebands around the exciting RF to verify nonexistence of coherent beam excitations
- Betatron resonance at $f_{q_y} = f_{\mathrm{rev}}(2 - q_y) \stackrel{!}{=} f_{\mathrm{RF}} = 871\,\mathrm{kHz} \Leftrightarrow q_y = 0.839$





- RF ExB dipole indeed works as Wien Filter, switching off the compensating E field clearly shows induced coherent beam oscillations

References

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