

# A novel injection scheme using R.F. manipulation for SOLEIL upgrade

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Accelerators and Engineering Division

- Upgrade project
- Top-Up injection process
- Manipulation in longitudinal plane
- Analogy between transverse and longitudinal planes
- Summary

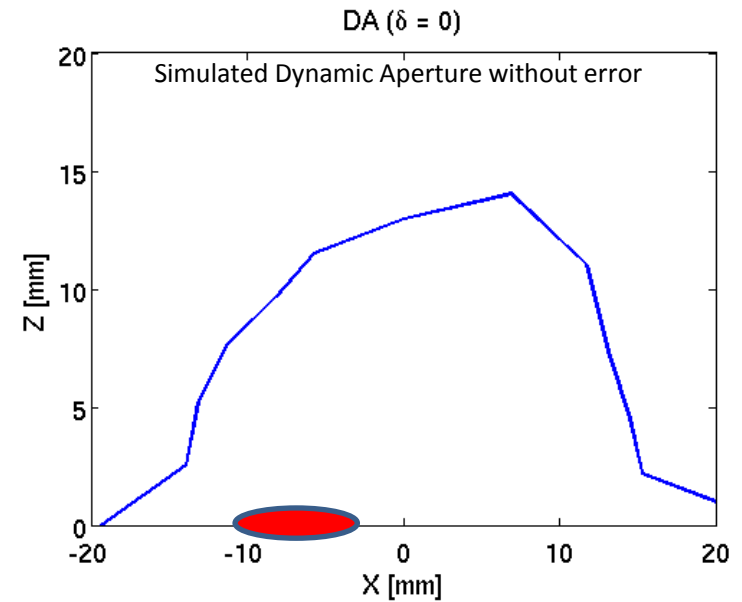
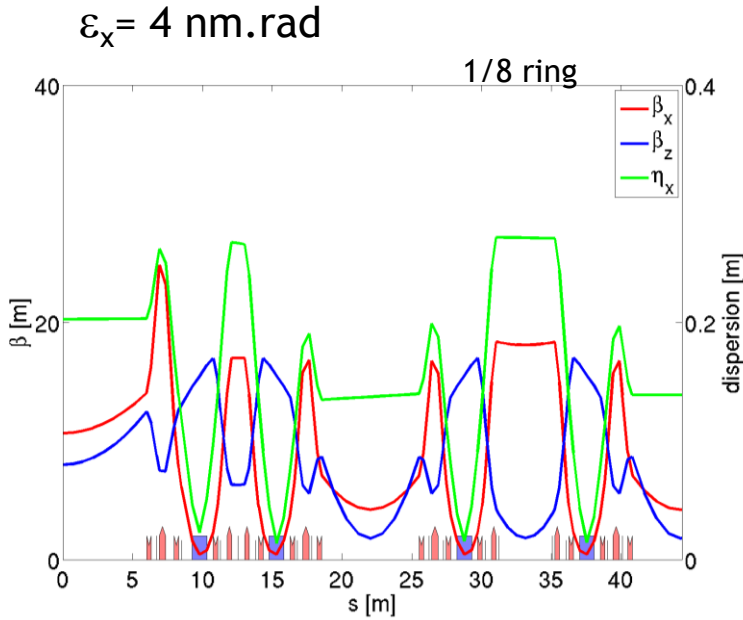
## Future upgrade of SOLEIL →

Reduce the horizontal emittance **below 100 pm.rad** in order to maximize the intensity of **coherent photon flux** arriving at the beamlines, especially in the **soft tender X-rays range up to 3 keV**.

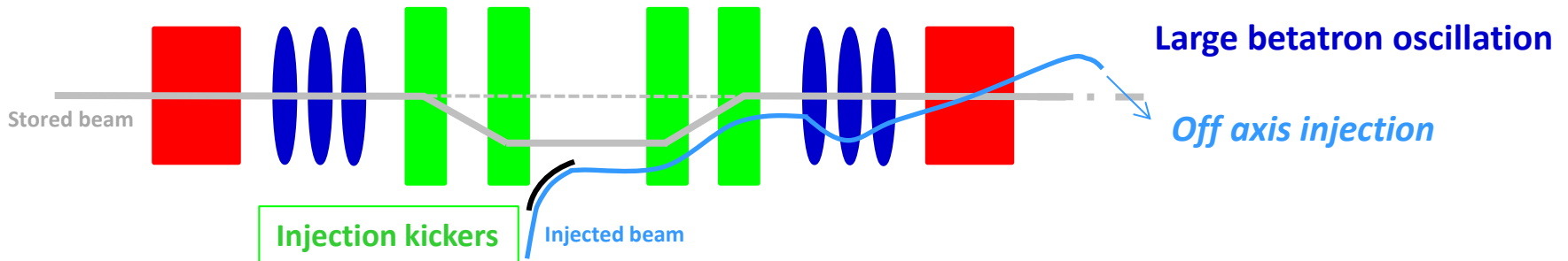
Constraints among a long list:

- **Reuse** of the existing tunnel and its **radiation shielding wall** → machine with **same length of 350 m and specific geometry** to maintain the existing insertion device source points **as much as possible**.
- Preserve a current of **500 mA** in multibunch operation, preserve **time structure** and **time resolved** operations with top-up injection.

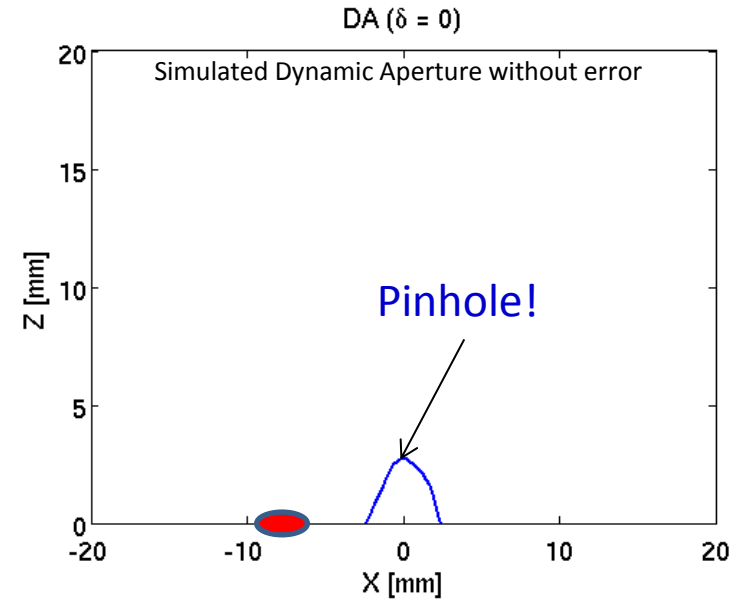
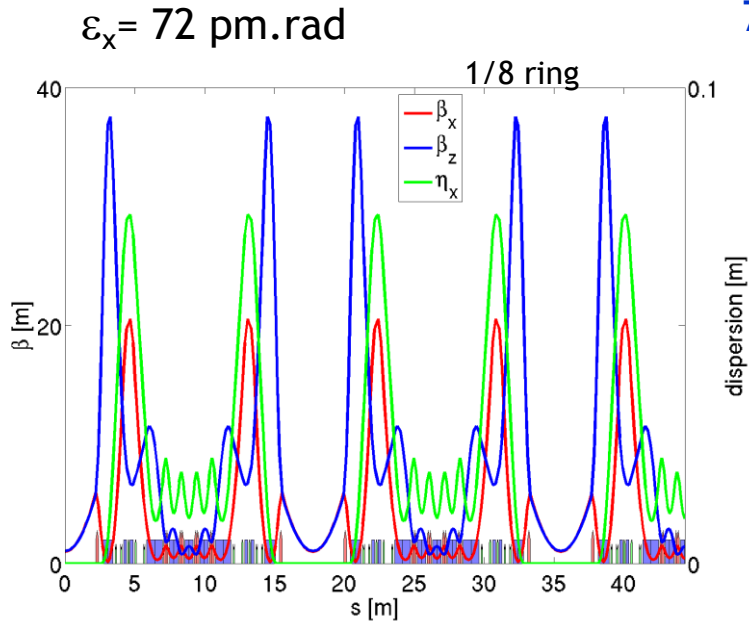
## Present SOLEIL lattice



Off axis injection of the Booster beam

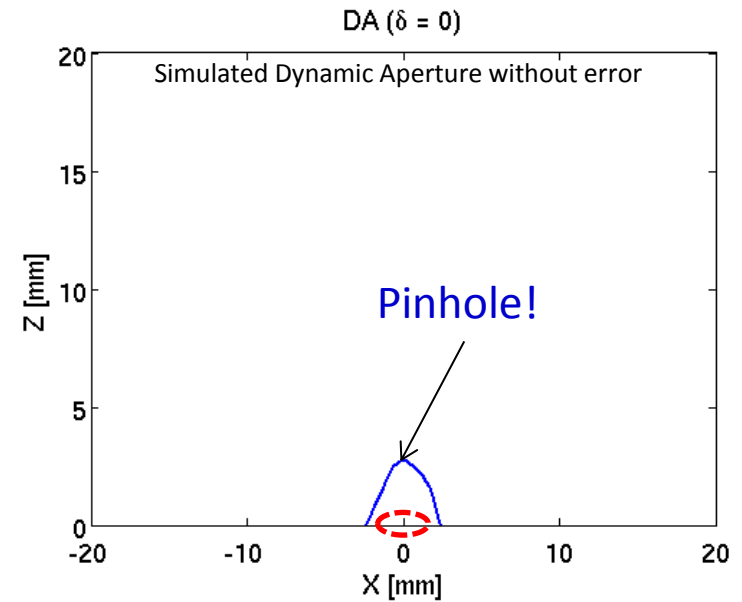
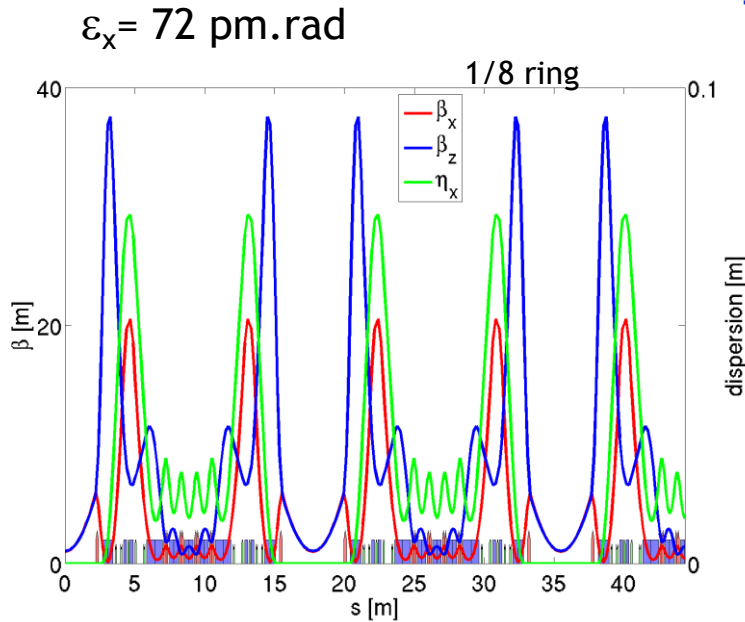


## Baseline lattice for Upgrade: 7BA structure



Forget OFF axis injection!

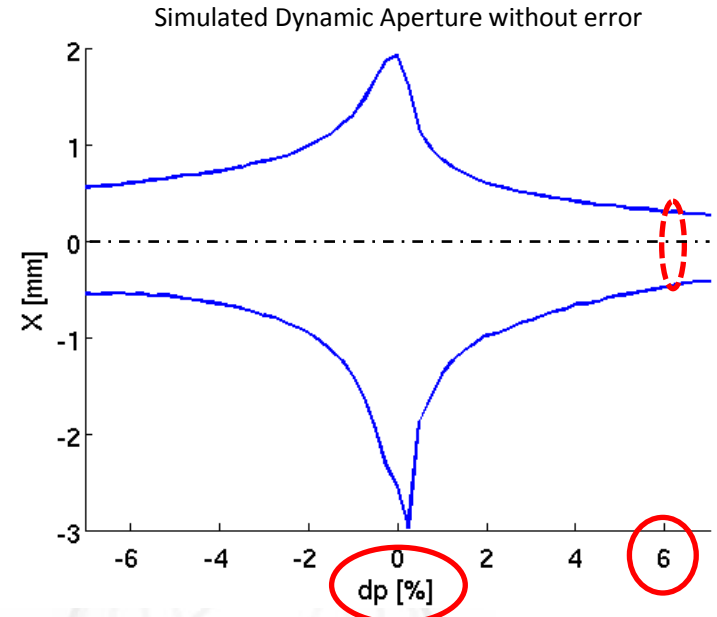
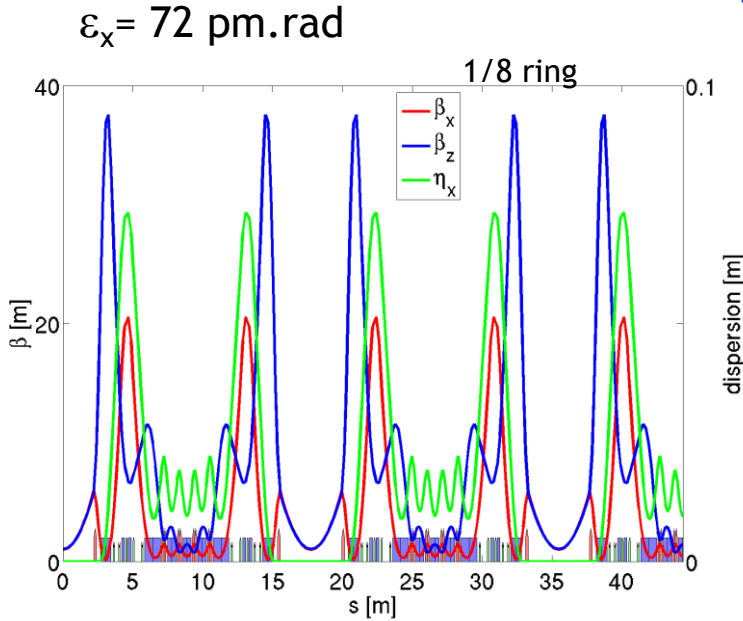
## Baseline lattice for Upgrade: 7BA structure



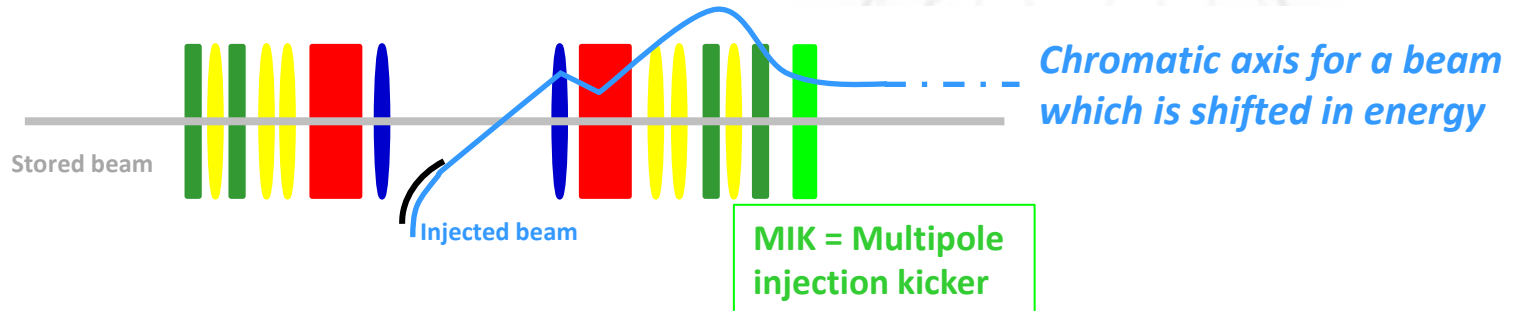
Try ON axis injection

But standard on-axis injection scheme (swap-out) requires **ultra-fast kickers** that are far from feasibility in SOLEIL case (352 MHz).

## Baseline lattice for Upgrade: 7BA structure

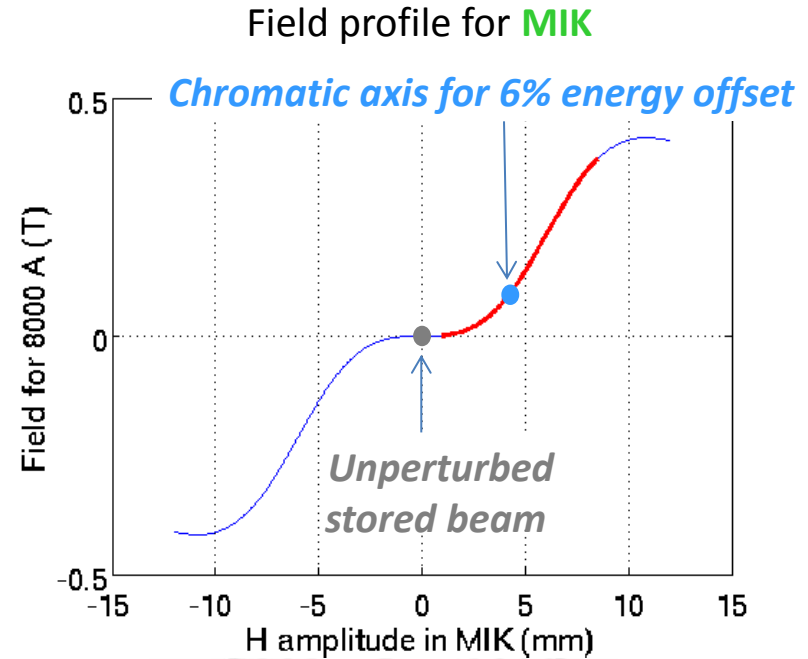


**This is an ON (chromatic)-axis injection!**



The MIK is a magnetic device with zero field on axis (no perturbation of the stored beam), and a field off axis that will kick the injected beam on the chromatic axis.

*Device already installed on MAXIV Lab., soon on SOLEIL (collaboration SOLEIL, MAXIV Lab.).*

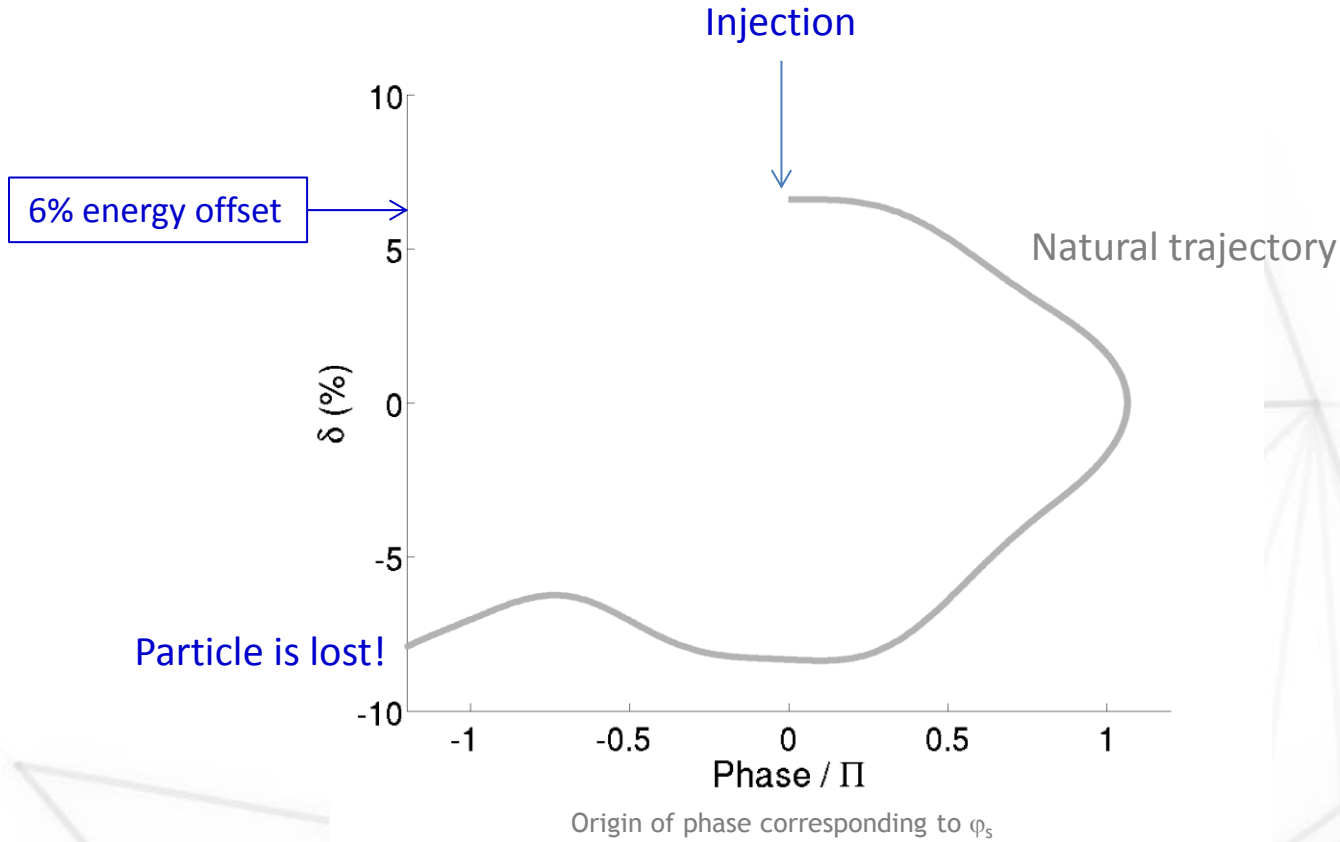


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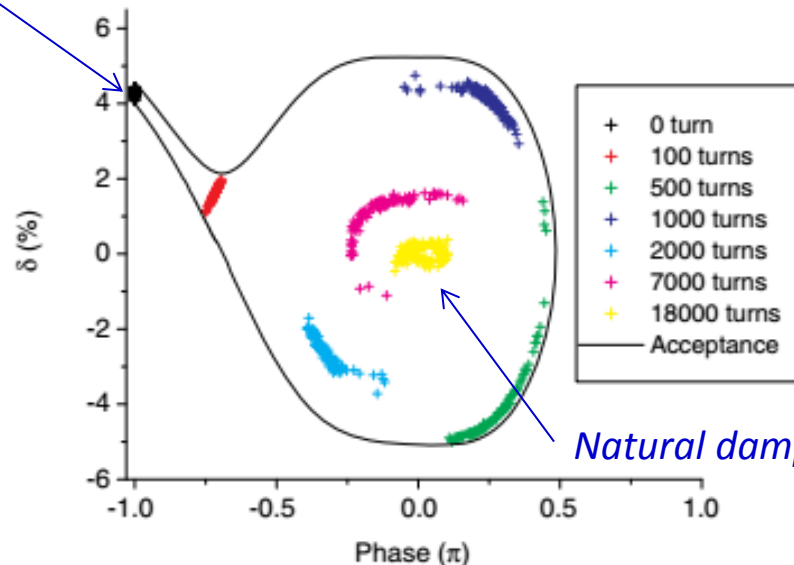
How to capture a particle which is shifted in energy (« off-momentum »)?



## How to capture a particle which is shifted in energy (« off-momentum »)?

Idea from SLS group: use the natural golf club shape of the longitudinal plane to inject and store an off-momentum beam, in top-up mode.

*Injection of an off-momentum beam at phase  $-\pi$*

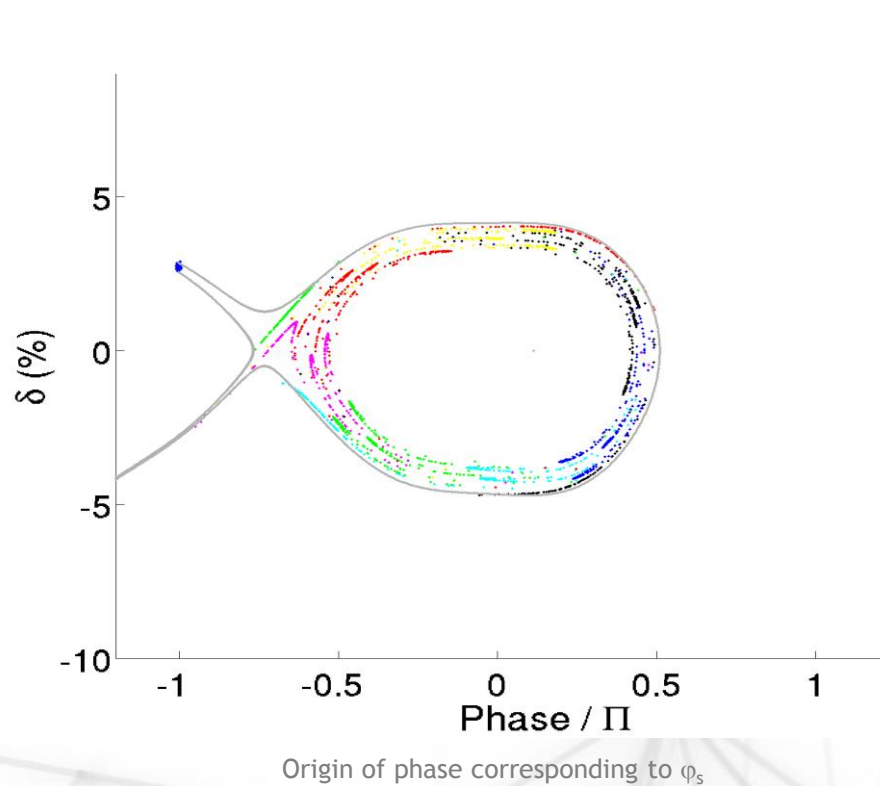


*Natural damping into the stored beam*

*Cf. M. Aiba et al., Longitudinal injection scheme using short pulse kicker for small aperture electron storage rings, Phys. Rev. ST Accel. Beams 18, 020701 (2015).*

## How to capture a particle which is shifted in energy (« off-momentum »)?

Applied to SOLEIL Upgrade (baseline lattice with 3<sup>rd</sup> harmonic cavity)

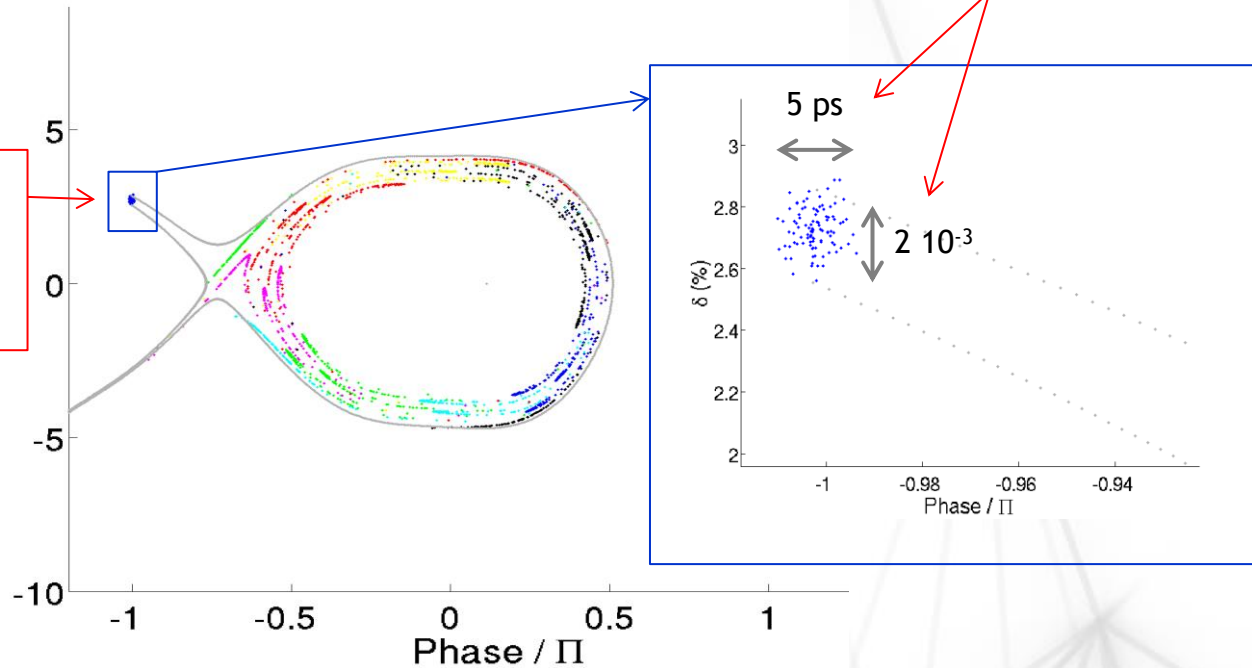


## How to capture a particle which is shifted in energy (« off-momentum »)?

Applied to SOLEIL Upgrade

Energy offset too low to spread enough the chromatic orbit and allow the use of a MIK

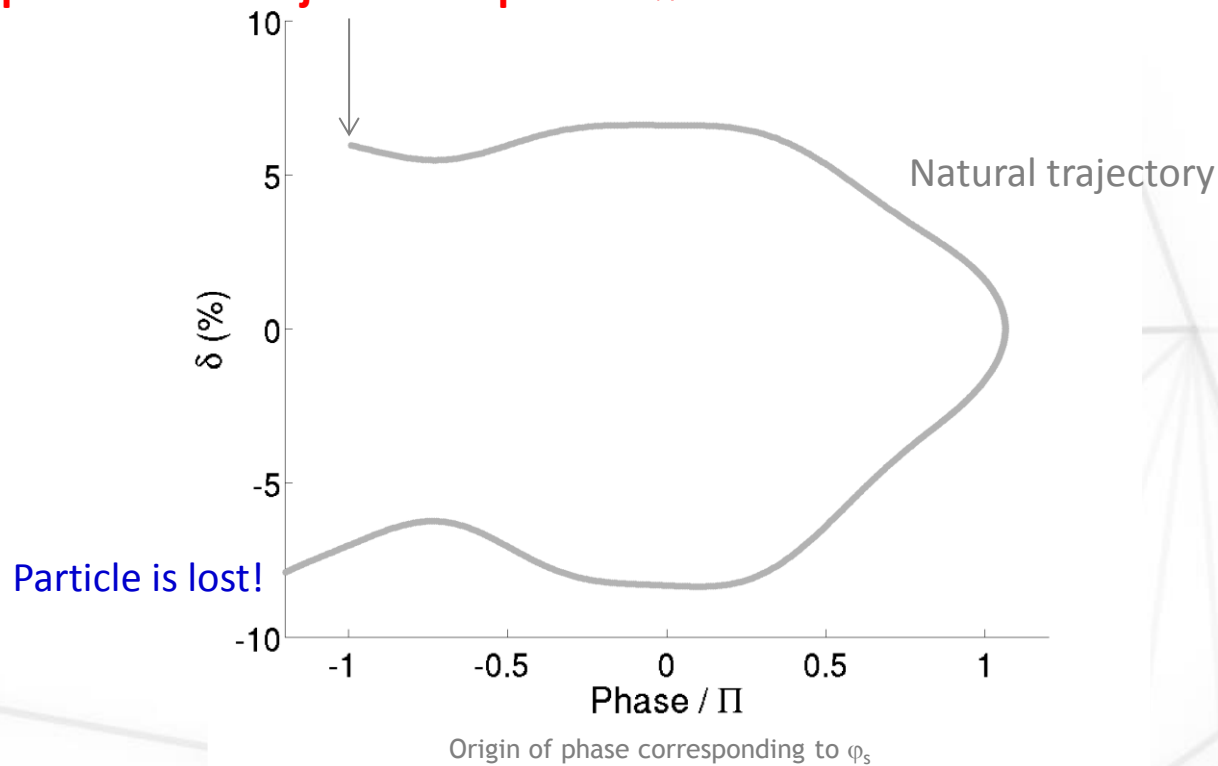
Injected bunch length and energy spread acceptance incompatible with Booster performances



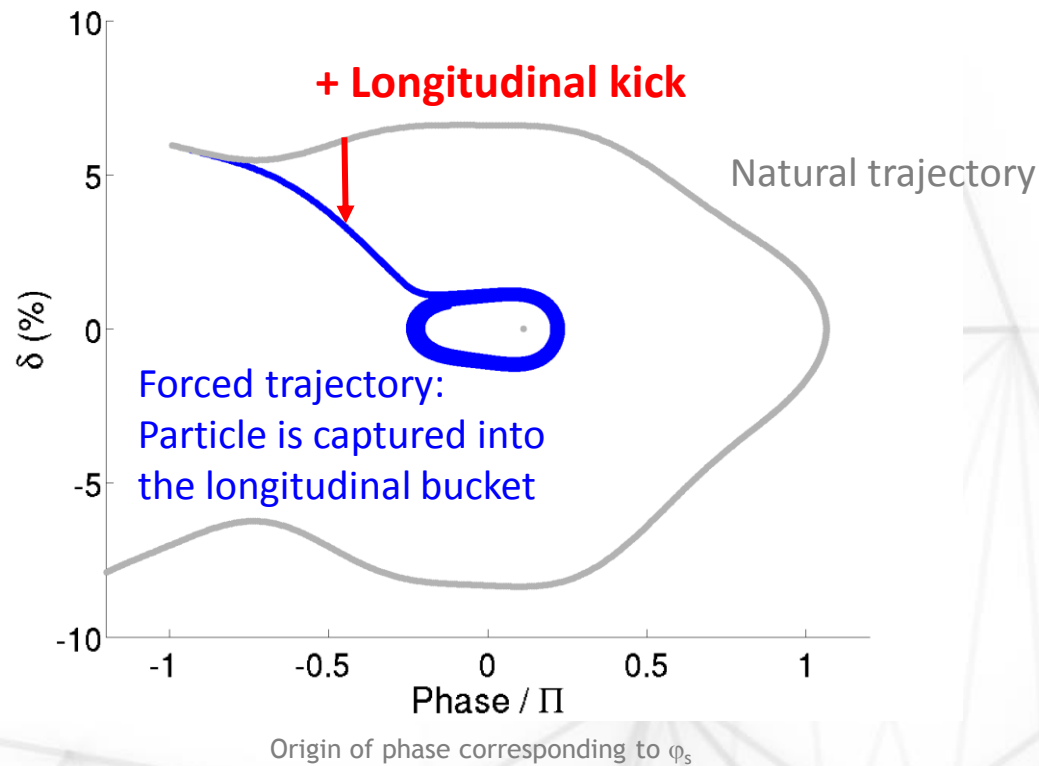
Origin of phase corresponding to  $\varphi_s$

How to capture a particle which is shifted in energy (« off-momentum »)?

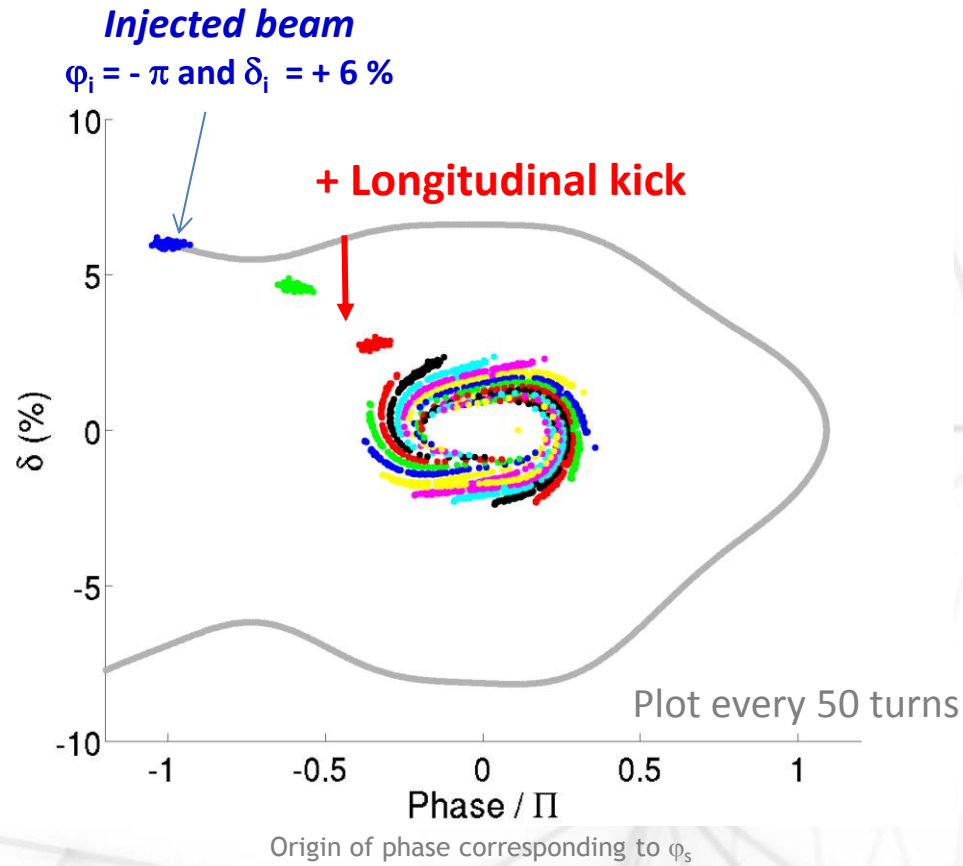
Keep the idea of injection at phase  $-\pi$



How to capture a particle which is shifted in energy (« off-momentum »)?



## Case of a realistic beam from a Booster



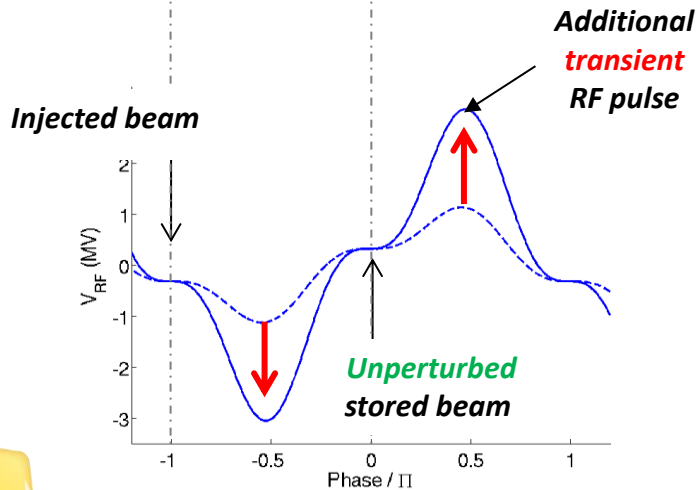
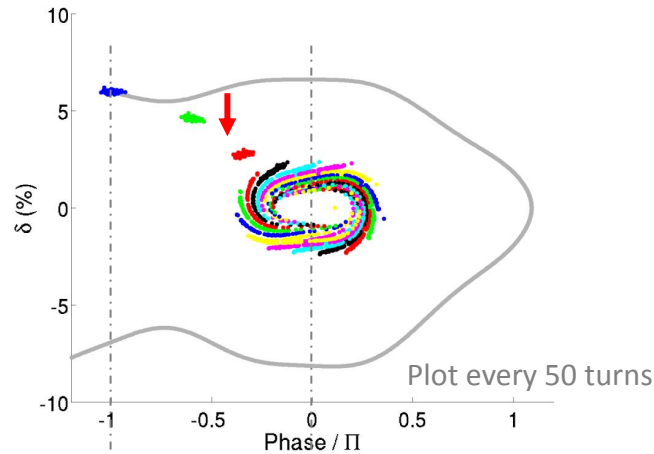
**The longitudinal kick is produced by an additional RF pulse, during the time of injection.**

**Procedure:**

- Switch on  $V_{RF\ add}$  before beam is injected @ phase  $-\pi$
- Switch off when beam reaches  $\varphi_s$ , after  $\sim 200$  turns

**Requirements:**

Do not perturb the stored beam



--- Main 352 MHz RF pulse and its 3<sup>rd</sup> harmonic for operation

$$V_{\text{main}} = 0.9 \text{ MV}$$

$$U_0 = 310 \text{ keV/turn}$$

— + additional pulses during injection:

$$V_{\text{ad } 352 \text{ MHz}} = 1.4 \text{ MV} + \text{shifted by } \varphi_s$$

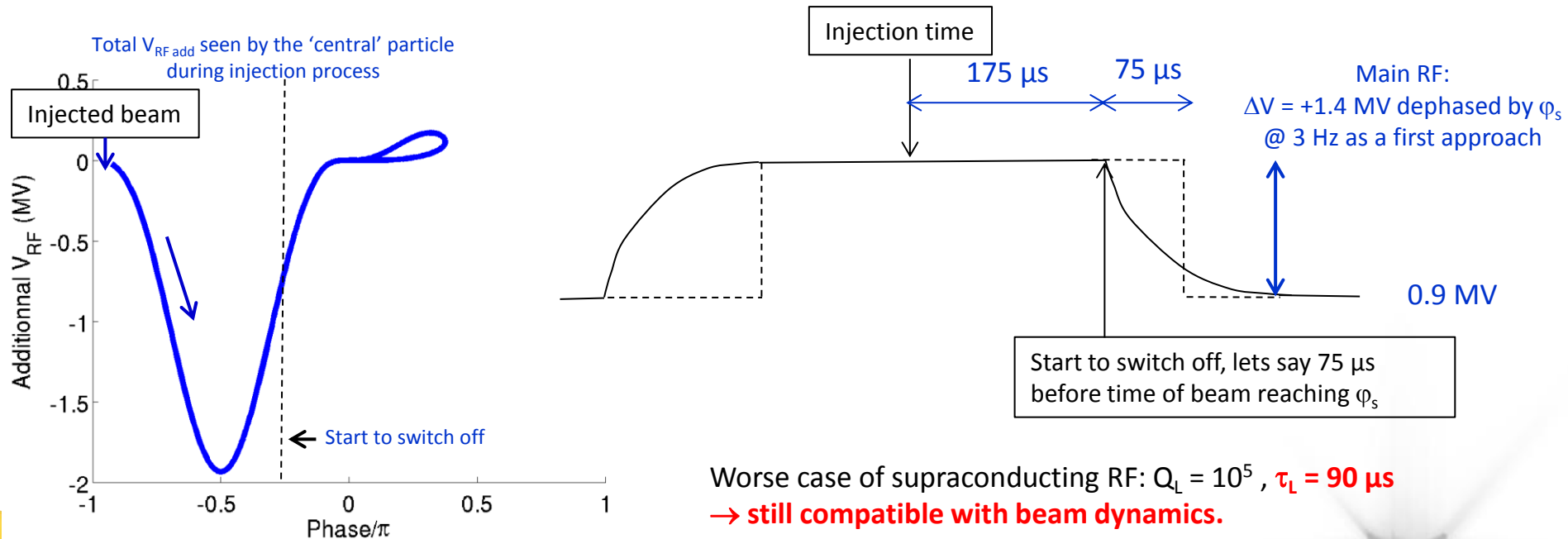
$$V_{\text{ad } 3\text{rd}} = V_{\text{add}} / 3$$



Switch on / off takes into account the loaded quality factor  $Q_L$  of cavities:  $\tau_L = \frac{2 Q_L}{2 \pi f_{RF}}$

One must consider:

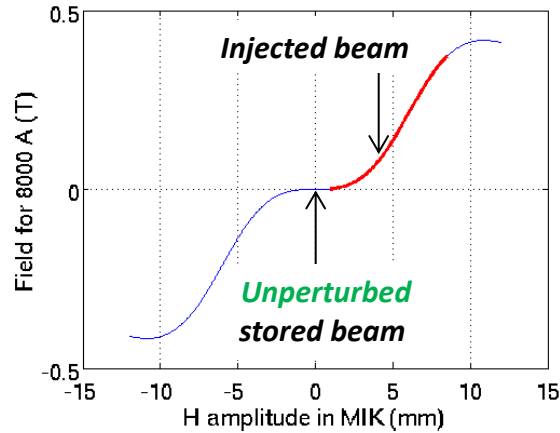
- How to get similar  $\tau_L$  for 3<sup>rd</sup> HC compared to main RF
- The phase control of main RF during voltage change



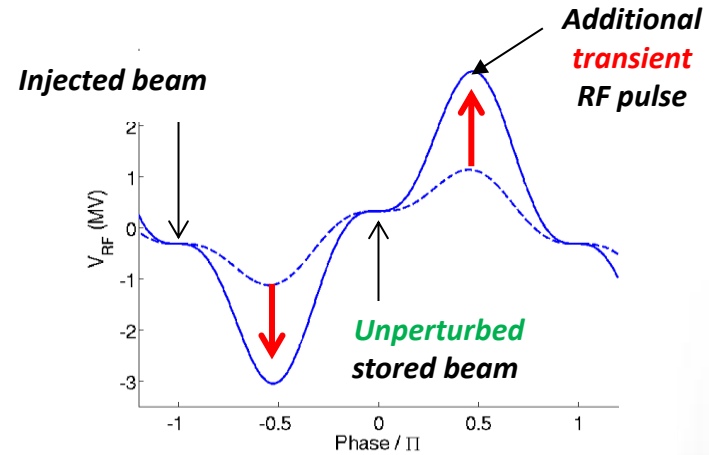
A beam with energy offset is put on **chromatic axis** with a **transverse Non Linear Kicker** (MIK) ...

... and launched from an offset phase ( $-\pi$ ), its energy is damped thanks to a **longitudinal Non Linear Kicker** (transient RF pulse - main and harmonic).

Field profile for **Transverse NLK (MIK)**



Voltage profile for **Longitudinal NLK (RF)**



- ❑ The use of a Transverse NLK (MIK) allows to inject an off-momentum beam ON (chromatic) AXIS. Unlike swap-out injection method, this doesn't require very fast kicker, but a 'slow' MIK.
  
- ❑ Then the beam is captured in the longitudinal plane thanks to a Longitudinal NLK. No short injected beam is needed. Damping process in longitudinal plane is accelerated.
  
- *Impact of errors are under investigation (Injector, Storage Ring magnets, R.F.), together with simulation on different lattices.*
- *R.F. tests are under way (see presentation P. Marchand)*
- *Issue on Harmonic Cavity: is there any possibility not to modulate its voltage during injection, without any impact on stored beam?*