TWIICE 2014
Topical Workshop on Instabilities, Impedances and Collective Effects
Synchrotron SOLEIL, 16-17 January 2014

Summary of the two-stream instability session

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Based on input from the presentations of
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N. Wang, T. Perron

Positron machines

- Primary electrons (mainly photoemission)
- Acceleration and secondary electron production

↓

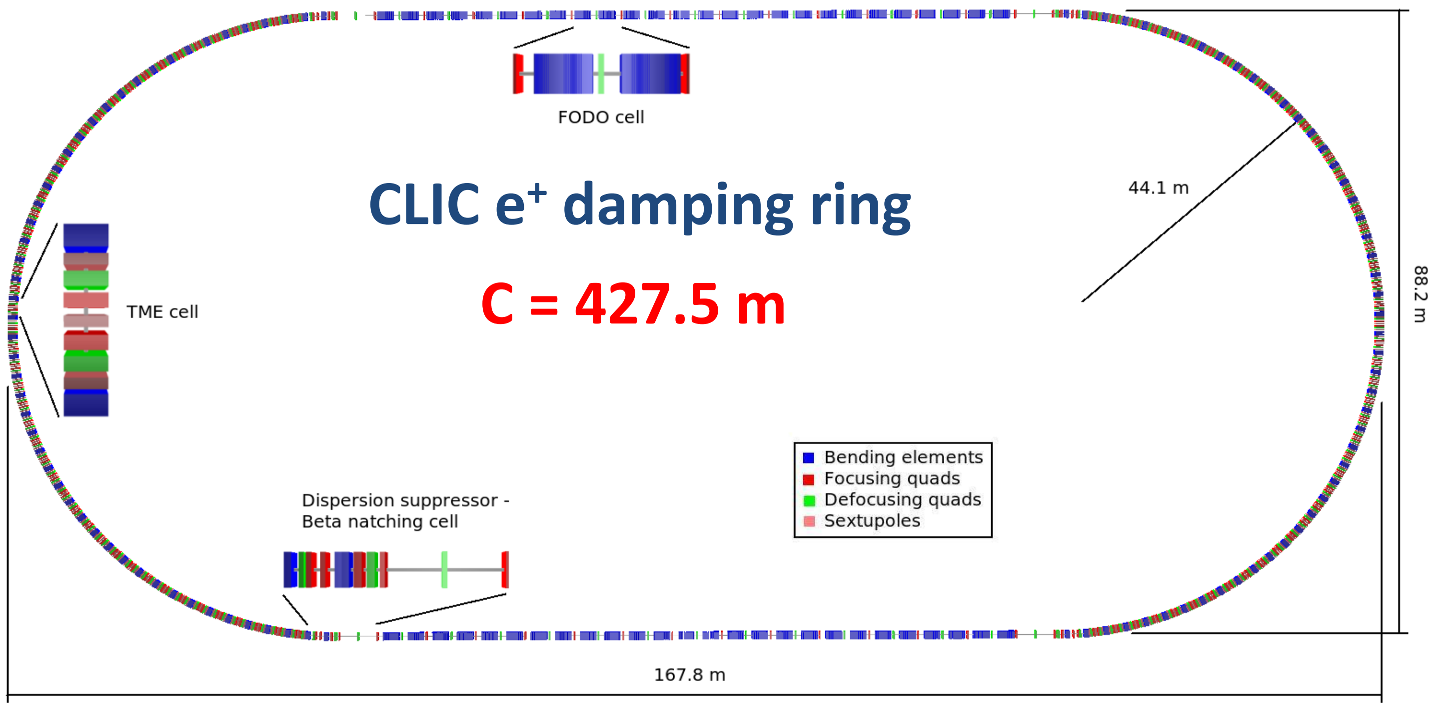
- Multi-bunch electron cloud build up
- Detrimental effects
- Mitigation/suppression needed

Electron machines

- Ions generation (mainly gas ionization)
- Acceleration and trapping

↓

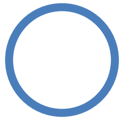
- Multi-bunch accumulation
- Beam instability
- Very good vacuum and vacuum composition needed



E-cloud aspects have been investigated in three families of devices

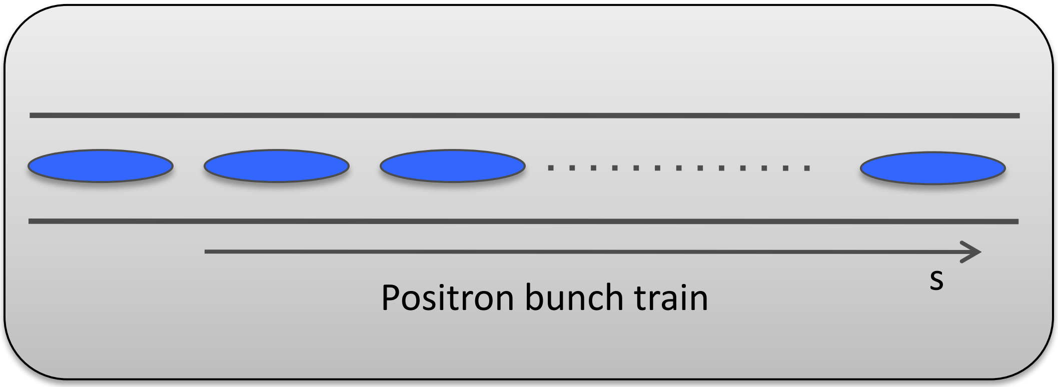
Wiggler
a=40mm, b=6mm
L_{tot} = 104 m

Dipole
a=40mm, b=9mm
L_{tot} = 58 m

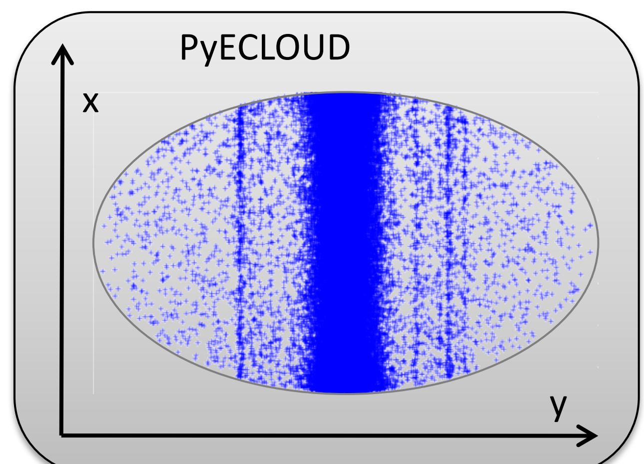


Quadrupole
a=9mm, b=9mm
L_{tot} = 86 m

ELECTRON CLOUD BUILD UP



Primary/secondary electron production (PEY, SEY)



** This process is **only slightly dependent** on the beam transverse emittance

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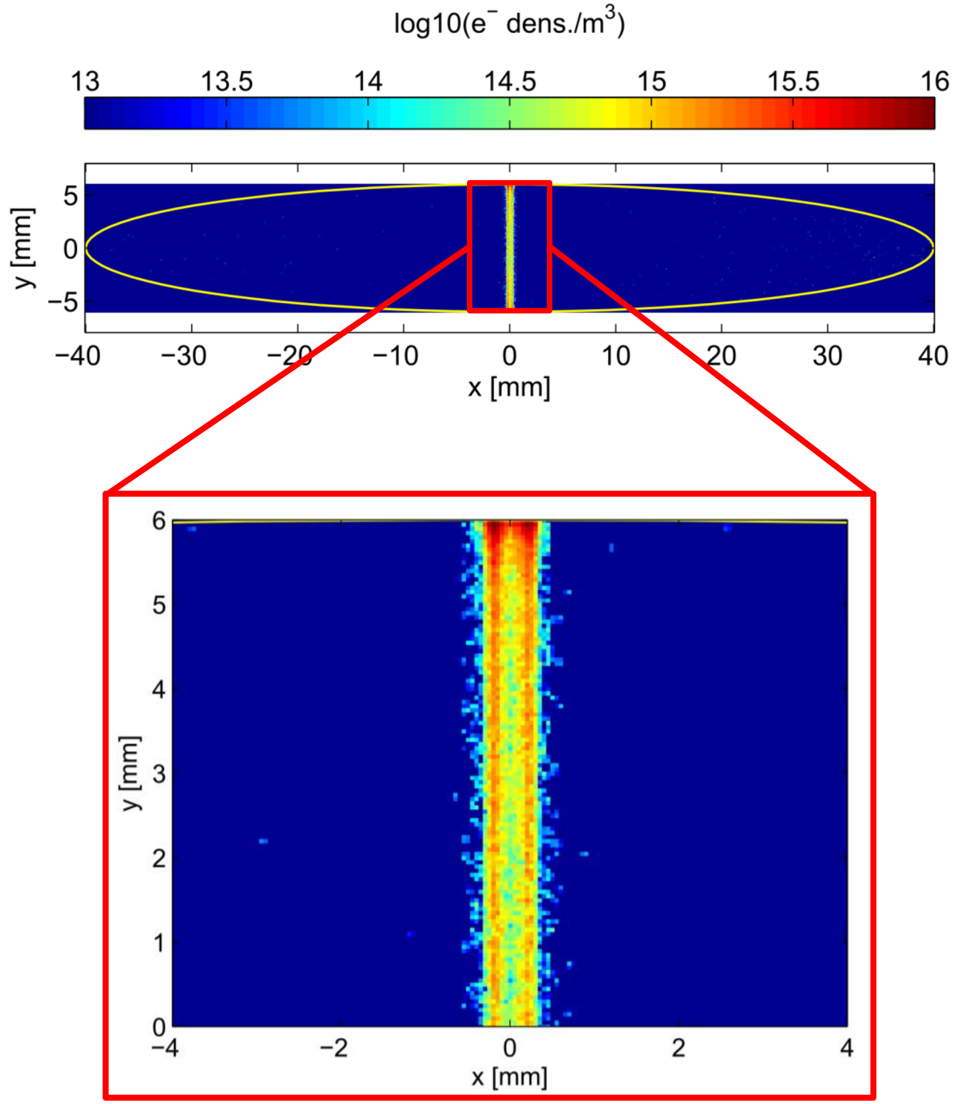
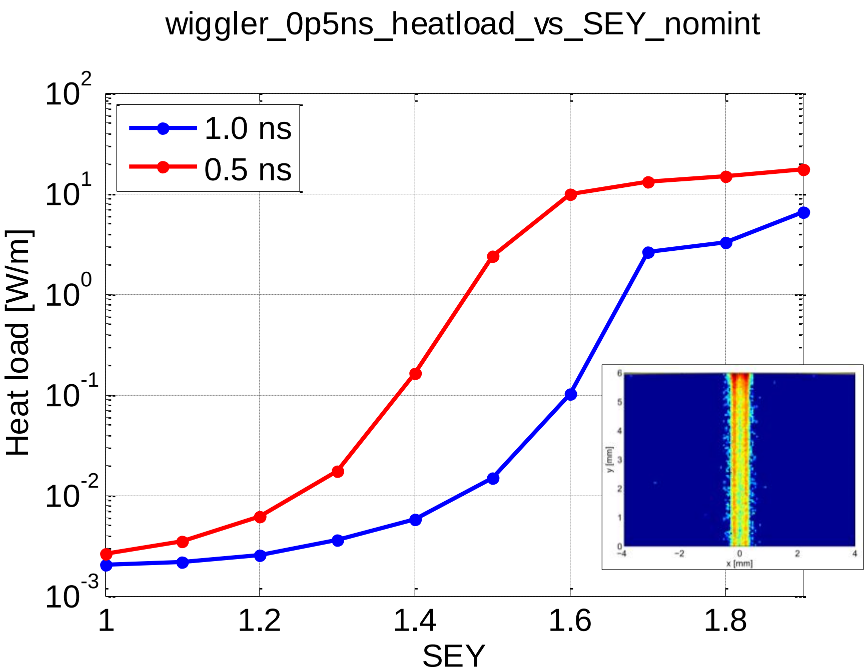
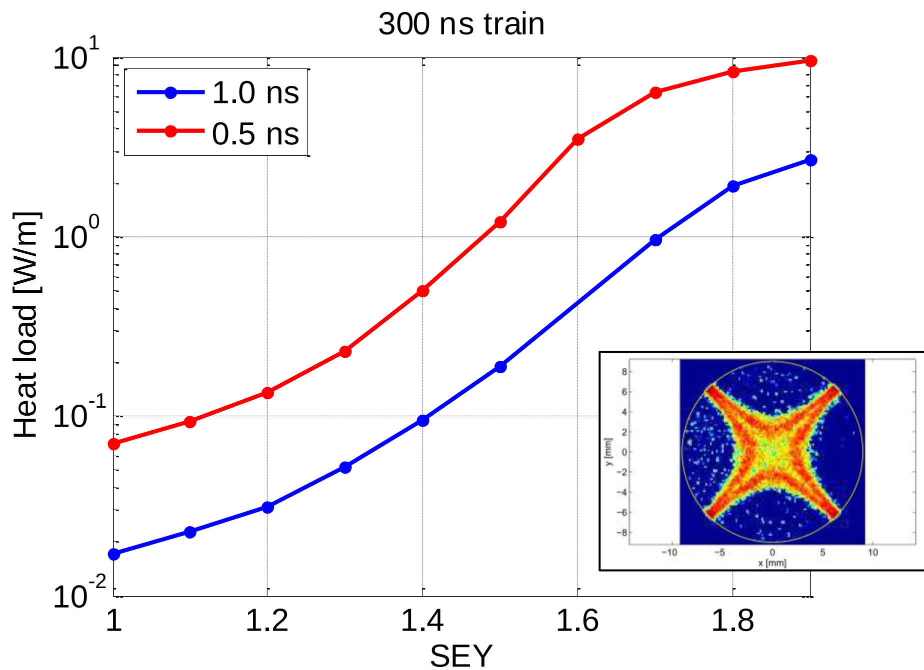
⇒ Challenging simulation scenario

- Short bunches → Short time step
- Small emittance → Beam size 10^4 smaller than chamber size
- In the cases of **wigglers and dipoles** e^- in a **narrow stripe** close to the beam → Fine grid needed for Poisson solver

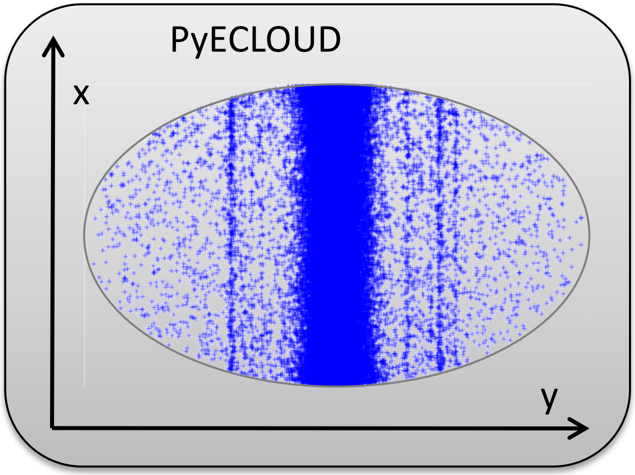




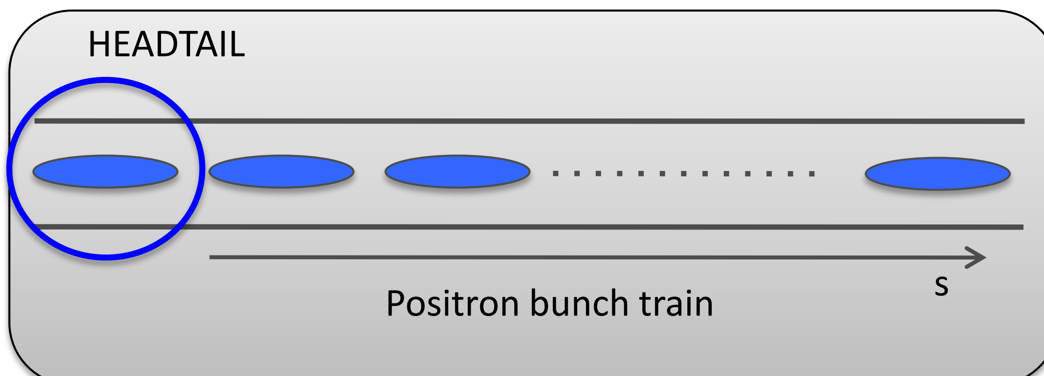


- Thresholds and saturation values **lower for 0.5 ns**
- Large **e^- densities (>1e13) at the beam location**
- E^- in narrow stripe in wigglers/dipoles, around the quadrupole field lines in quads.
- Local low SEY coating or clearing electrode for full e-cloud suppression in all cases possible

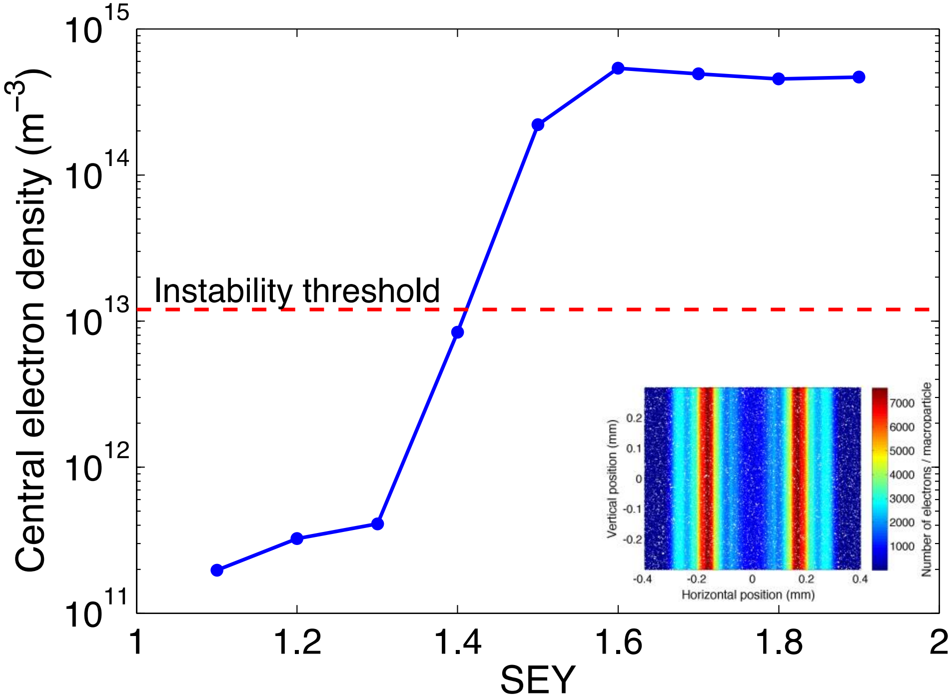
ELECTRON CLOUD DRIVEN SINGLE BUNCH INSTABILITY

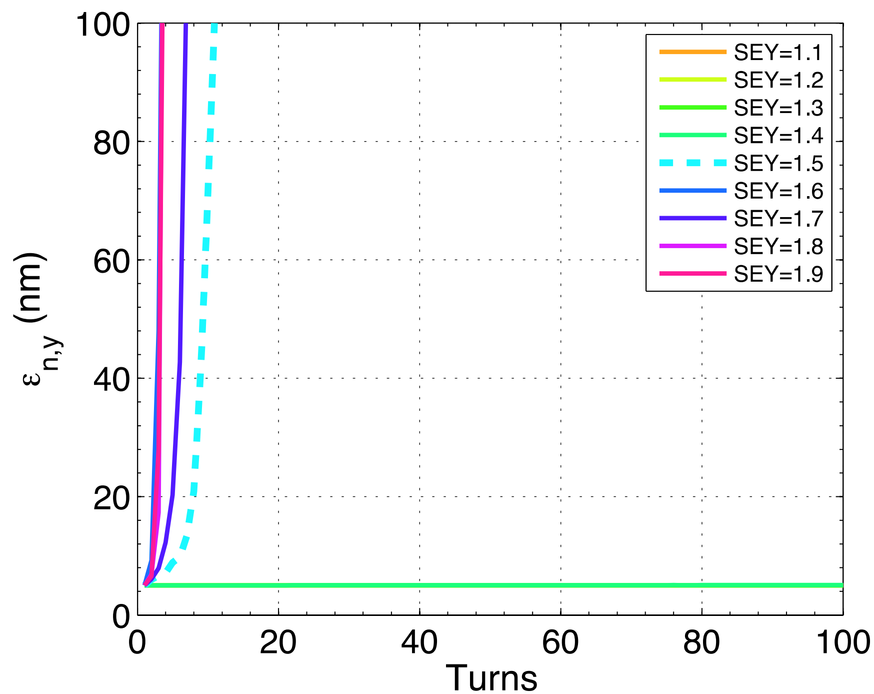


Equations of motion of the beam particles



** This process is **strongly dependent** on the beam transverse emittance





- ⇒ Beam becomes unstable (few turns rise time) as soon as electron build-up reaches saturation in wigglers
- ⇒ Chromaticity does not help
- ⇒ Consistent with threshold density found with uniform electron distributions (1.3 x 10^{13} m^{-3})

MITIGATION/SUPPRESSION TECHNIQUES

Possible Solutions

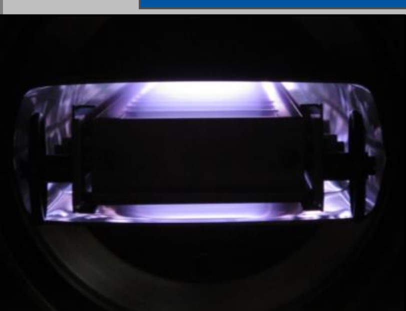
Clearing electrodes installed along the vacuum chambers (only local, impedance)

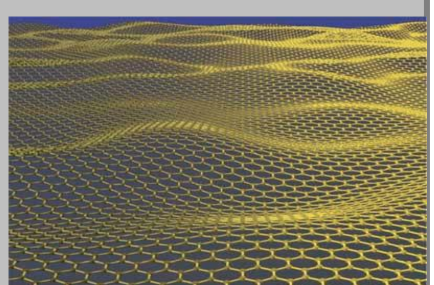
Solenoids (only applicable in field-free regions)

Tolerate e-cloud but damp the instability: feedback system

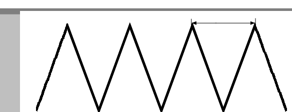
Machine scrubbing during operation
- Limited by reachable SEY
- Depends on e- energy
- Relies on surface graphitization

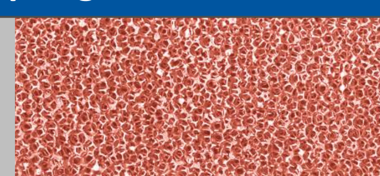
Applying on the wall thin films with intrinsically low SEY
- NEG coating (helps vacuum)
- C coating (no activation)



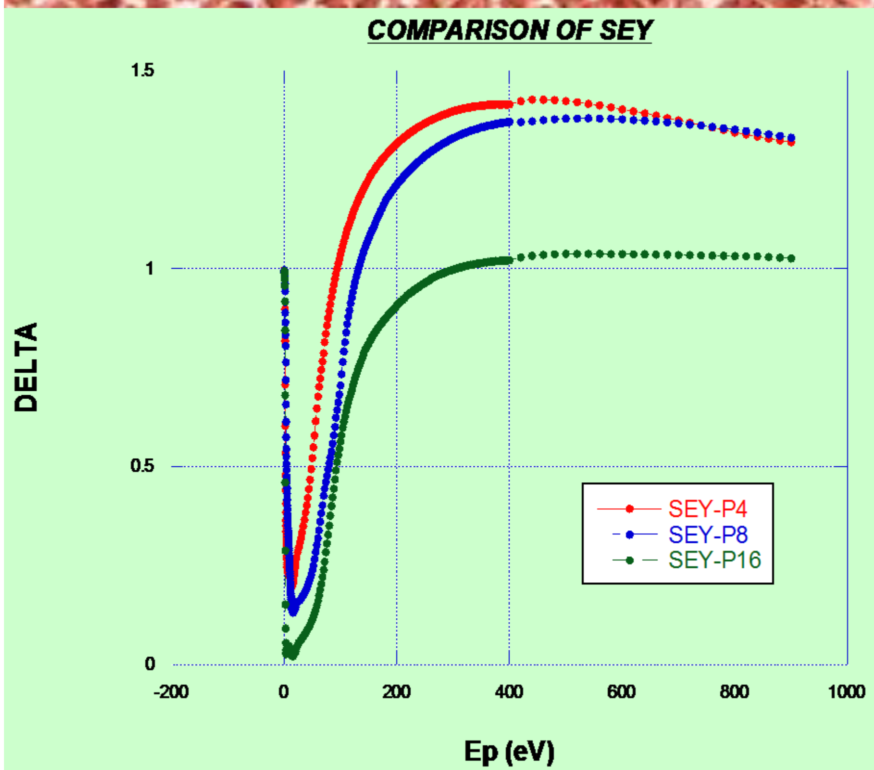


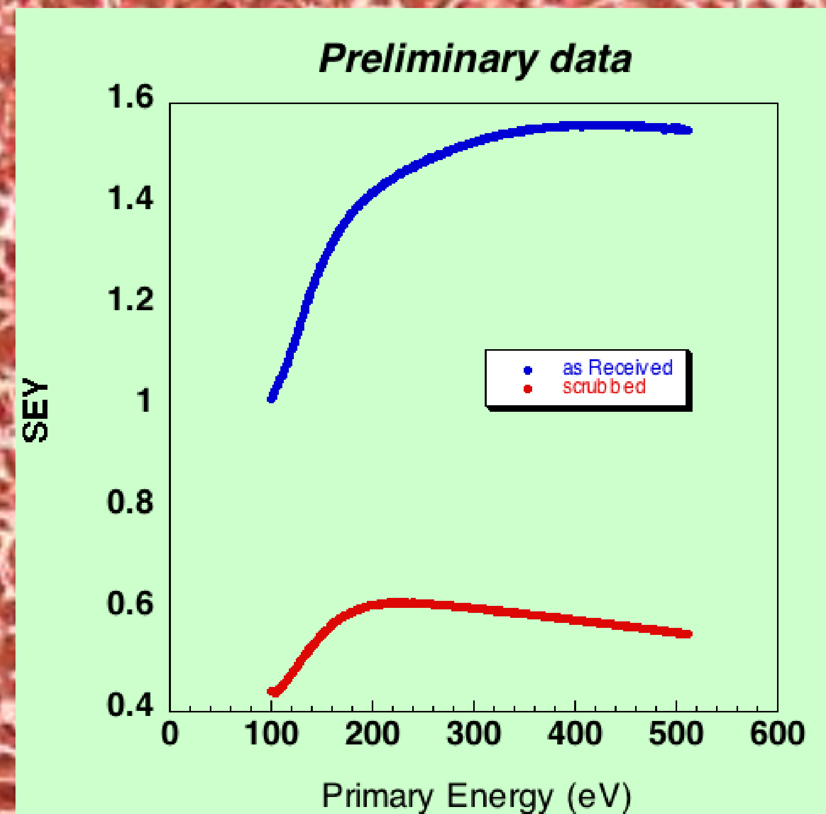
Surface roughness to stop secondary electrons
- Grooves
- Rough material coating
- Sponges





MITIGATION/SUPPRESSION TECHNIQUES → SPONGES





Impedance impact, vacuum behaviour, desorption properties are still under study

→ **seems very promising**

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→ **Mainly estimations based on analytical formulae for trapping condition and instability rise time**

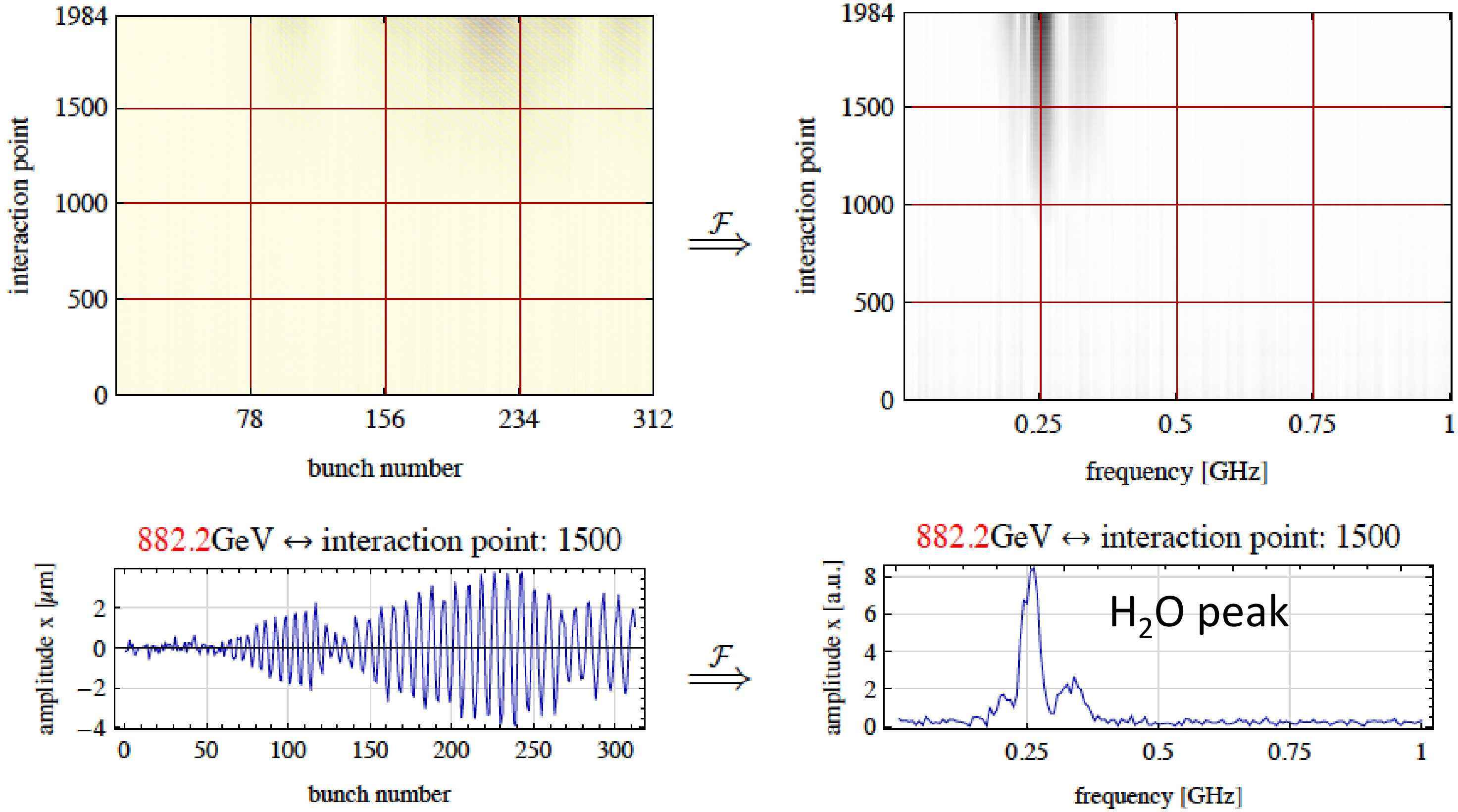
→ **Applied to Beijing Advanced Photon Source (BAPS) and ESRF upgrade**

→ **Detailed simulations foreseen, possibly including a transverse damper**

$$A_{\text{trap}} > \frac{N_b r_p L_{\text{sep}}}{2\sigma_{x,y}(\sigma_x + \sigma_y)}$$

$$\tau_{inst}^{-1}[s^{-1}] = 5\,p[Torr]\frac{N_b^{3/2} n_b^2 r_e r_p^{1/2} L_{sep}^{1/2} c}{\gamma \sigma_y^{3/2}(\sigma_x + \sigma_y)^{3/2} A^{1/2} \omega_\beta}$$

The CLIC Main Linac



→ **Vacuum specifications for CLIC long transfer line, Main Linac and BDS made with strong-strong multi-species FASTION code**

→ **Different vacuum compositions investigated, NEG & baked vacuum most favorable**

Observations

- Ion instabilities observed in APS (with additional He injection), PLS (with additional H_2 injection), SOLEIL, BESSY II, ELETTRA, ALBA
- **Fast beam ion instability** observed in electron rings
  - During commissioning/start up (chamber not yet conditioned, bad vacuum, feedback system not yet operational)
  - Because of some local pressure rise (e.g., directly connected to impedance induced heating)
  - Artificially induced by injecting gas into the vacuum chamber and raising the pressure by more than one order of magnitude (for studies)
- Usually less severe than predictions, stabilizing effects not included in existing models ?
- Quantitative comparison between theoretical predictions, simulations and measurements yet to be made
  - Experiment planned at Cesr-TA (April 2014)

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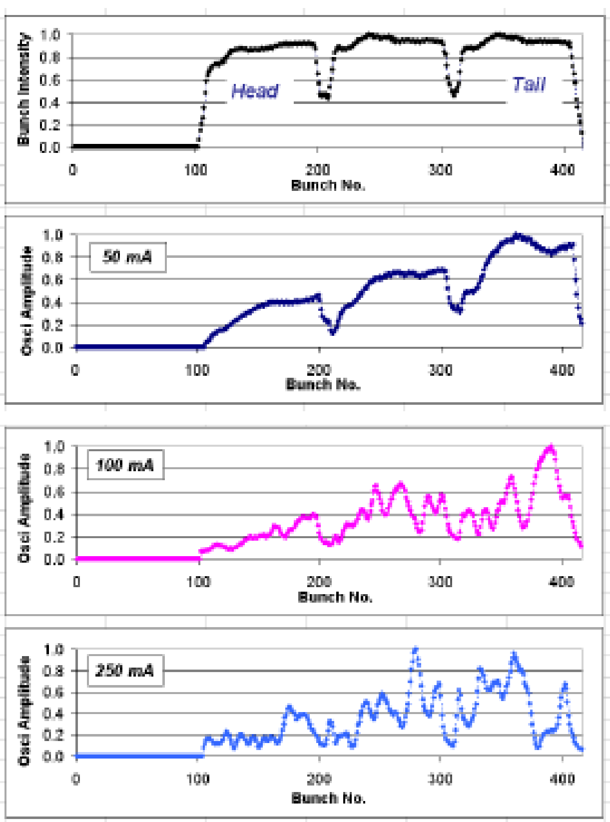
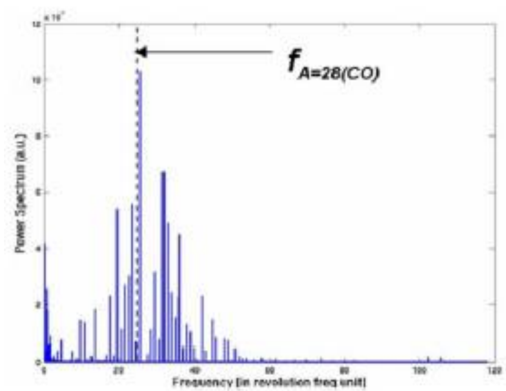
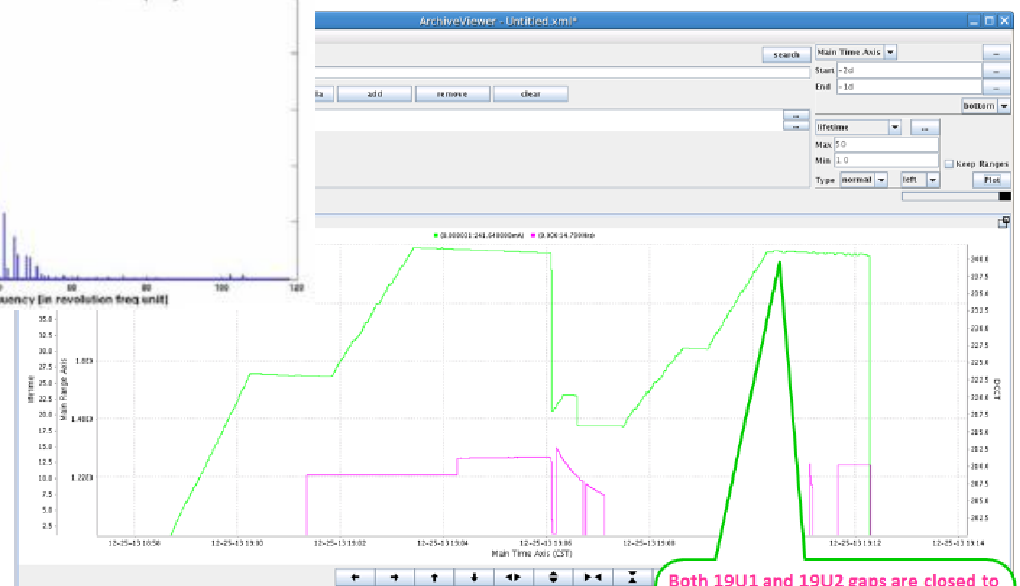
Observations (II)

- **Ions enhanced by local heating (outgassing) seem to trigger some recently observed high current instabilities @ SSRF and SOLEIL**





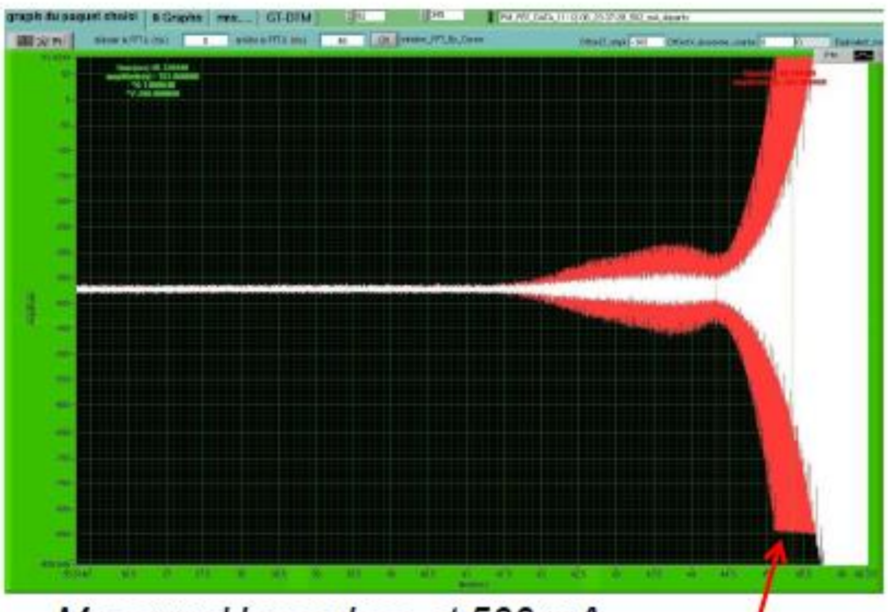


Both 19U1 and 19U2 gaps are closed to 6.5 mm. The beam stable for about 2 minutes before instability appears. We believe Resistive-Wall impedance will act on the beam instantly. The ion effects are the reason for the beam loss

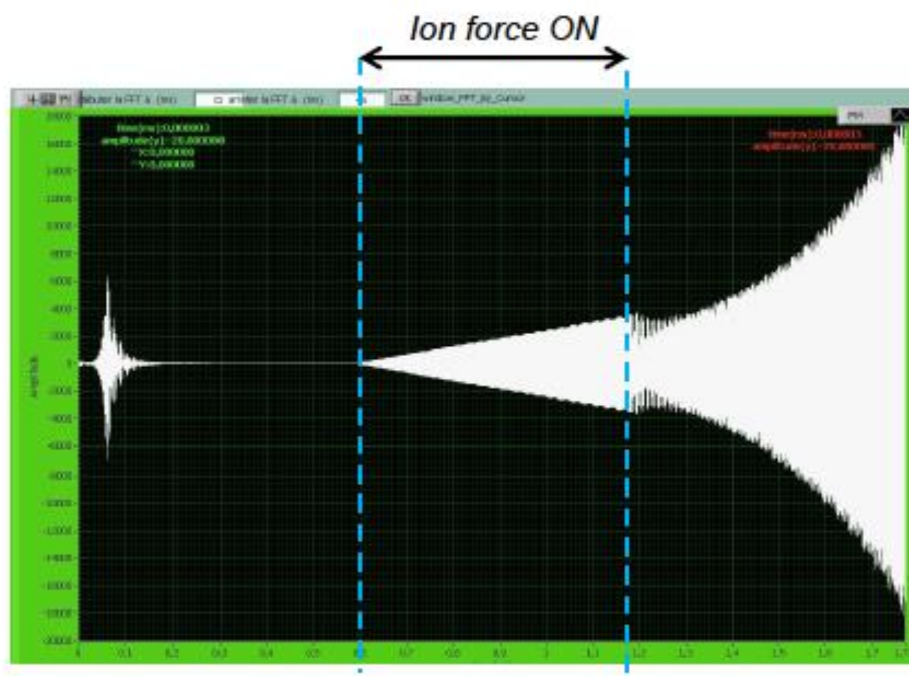
Courtesy Bocheng Jiang

Observations (III)

- **mbtrack simulations suggest that SOLEIL instability results from an intriguing interplay between resistive wall, ion effect and transverse feedback**



Measured beam loss at 500 mA
White: Beam, Red: TFB kick



Simulation: RW with temporal "shaker" excitation at F_{ion}

Wrap up

- Two-stream effects often affect the performance of running accelerators and can be a serious limitation for future low emittance rings

  → **Electron cloud formation and instabilities in CLIC DRs**

  - Studies carried out with detailed modeling
  - Electron cloud in wigglers not acceptable for beam stability

  → Promising ongoing research on mitigation or suppression techniques (C and sponge coating, scrubbing mechanism)

  → **Ion accumulation and instabilities**

  - Mainly analytical formulae used for future machine design, detailed simulations needed
  - Observations in running machines usually made in presence of vacuum degradation and with high intensity → important interplay between several effects (RW, FII, damper) observed
  - Beam-induced outgassing enhanced for machines with low-gap chambers and high intensity short bunches, → FI effects possibly more serious for future low emittance light sources