# SPS MD2128: Implementation of a dynamic extraction bump in LSS2

rMPP meeting – MD#4/5 2017 approval, 7 Nov 2017

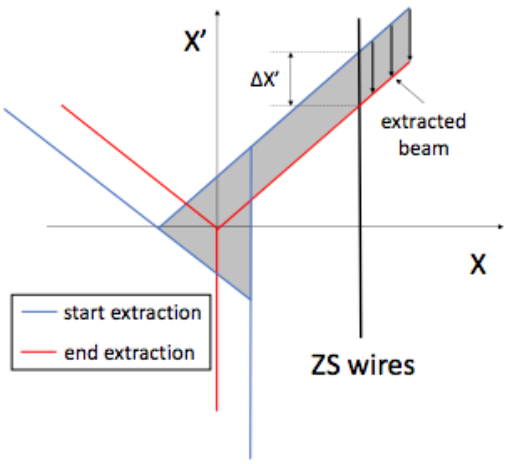
M.A. Fraser, L.S. Stoel, F.M. Velotti, CERN

# Overview

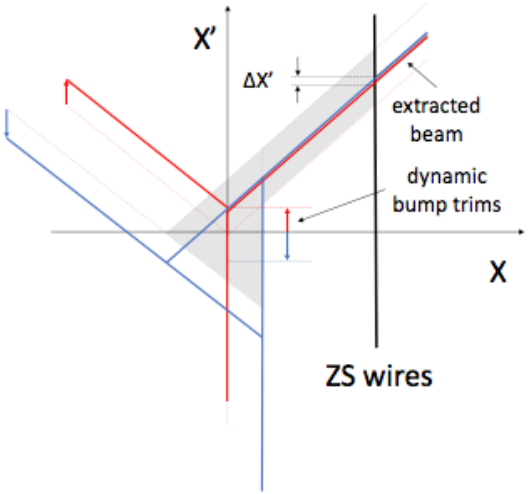
- Motivation for the MD
- ZS damage limits
- Preparations already performed 4$^{th}$ Oct 2017:
  - Very Low Intensity MTE ~2E11 ppp
  - Checks of orthogonal knobs
- MD procedure: relevant MP points highlighted

# Motivation for MD

- To demonstrate a reduction of losses ($\sim 6\%$) during slow extraction on the SFTPRO user at the electrostatic septum (ZS):
  - Superimpose two small additional orthogonal corrections (X, PX) to correct for the movement of the separatrix arm during the spill
  - Loss reduction depends on the effective septum thickness
  - Crucial for the effectiveness of other loss mitigation techniques, e.g. passive diffuser, active (crystal) diffuser (to be tested next year!)



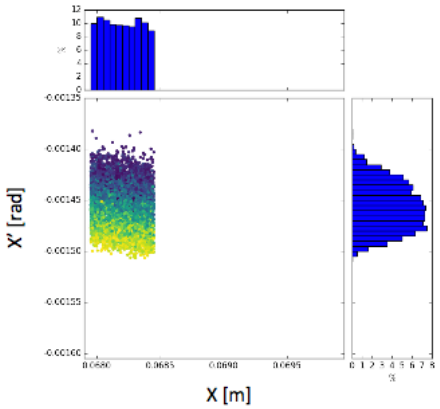

(a) without dynamic bump



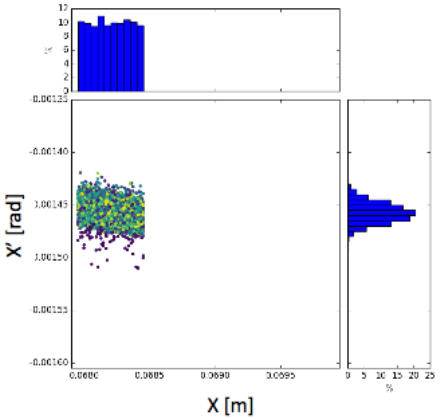

(b) with dynamic bump

# Motivation for MD

- To demonstrate a reduction of losses (~6%) during slow extraction on the SFTPRO user at the electrostatic septum (ZS):
  - Superimpose two small additional orthogonal corrections (X, PX) to correct for the movement of the separatrix arm during the spill
  - Loss reduction depends on the effective septum thickness
  - Crucial for the effectiveness of other loss mitigation techniques, e.g. passive diffuser, active (crystal) diffuser (to be tested next year!)




Without dynamic bump: $\sigma_{x'}$ = 22.7 mrad



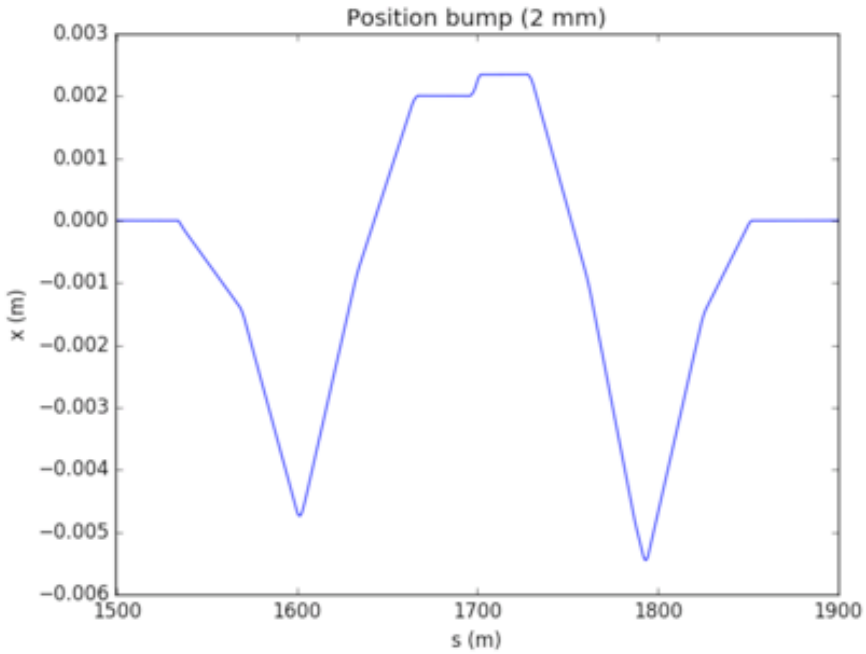

With dynamic bump: $\sigma_{x'}$ = 9.6 mrad
Orthogonal bump variation:
$\Delta x = \pm 1.1$ mm, $\Delta x' = \pm 64$ µm

# ZS damage limits

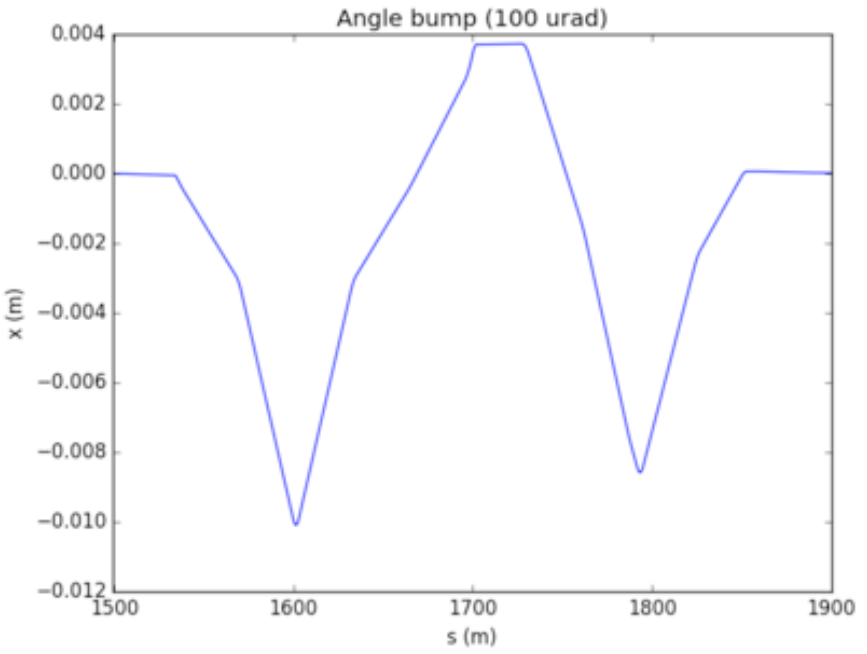
- Our best estimate on the damage limit for the thin 60 μm diam. W-Re wires comes from flying wire MDs carried out in the 90's:
  - The damage limit for today's ZS Tank 1 (10 years operation) is unknown…
  - However, from the MD's it is estimated at **1.9E12 circulating protons for a 60 μm wire at 0.7 m/s**
- Nominally, we will move the beam 1000 times slower ~mm/s
- A Very Low Intensity MTE beam has been developed to mitigate the risk with x10 lower intensity at 2E11 ppp:
  - Intensity so low that attenuators have to be removed from LLRF: we will operate in a dedicated mode with no higher intensity beams in the super-cycle in the SPS: *signal-to-noise ratio for LSS2 BLMs looks OK*
- We have checked recently the fast LSS2 BLM reaction time and it was estimated at 800 μs (<40 turns):
  - Interlock thresholds to be set accordingly with the low intensity
  - Accident in 2007 pushed circulating beam over ZS wires in ~6 ms

# Orthogonal bumps

- Orthogonal X and PX knobs (move only X or only PX at upstream end of ZS) are superimposed onto the extraction bump knob:



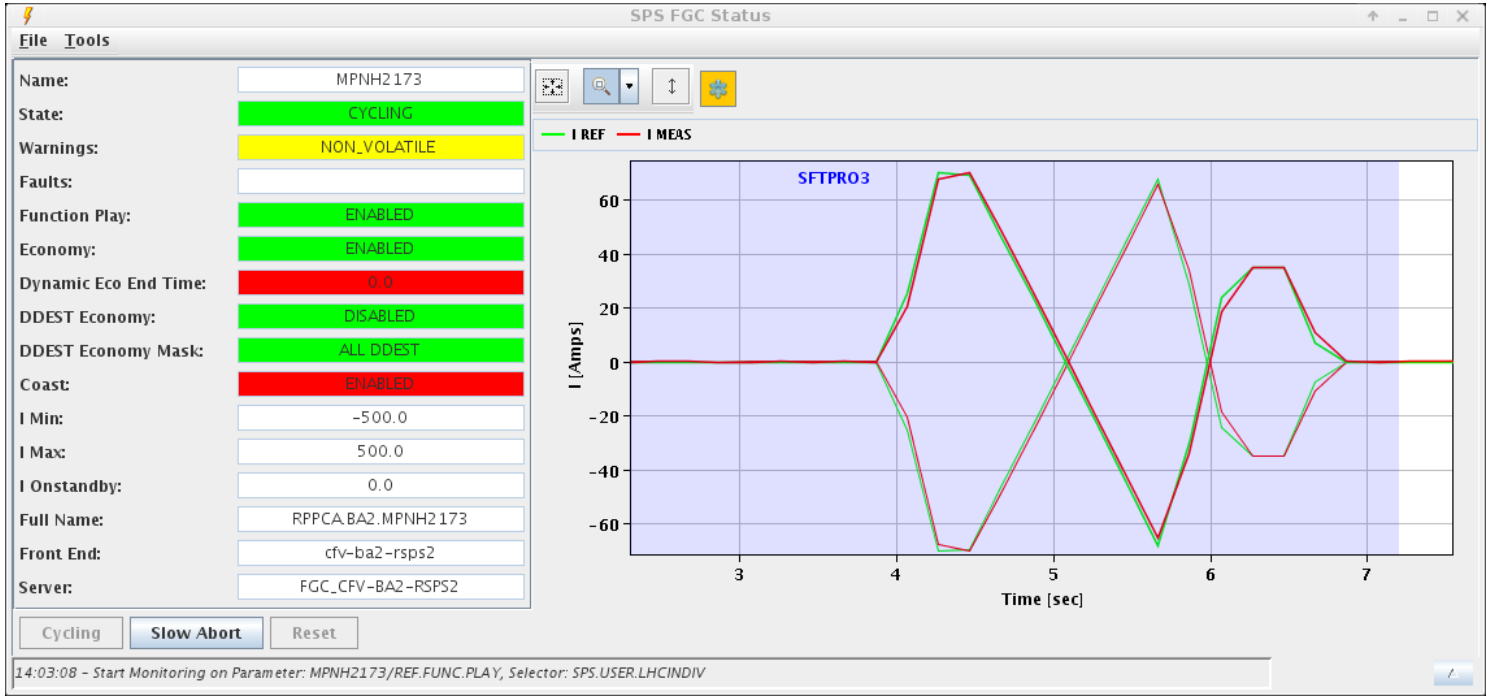

(a) X bump ($X_{ZS}$ = 2 mm)




(b) PX bump ($PX_{ZS}$ = 100 µrad)

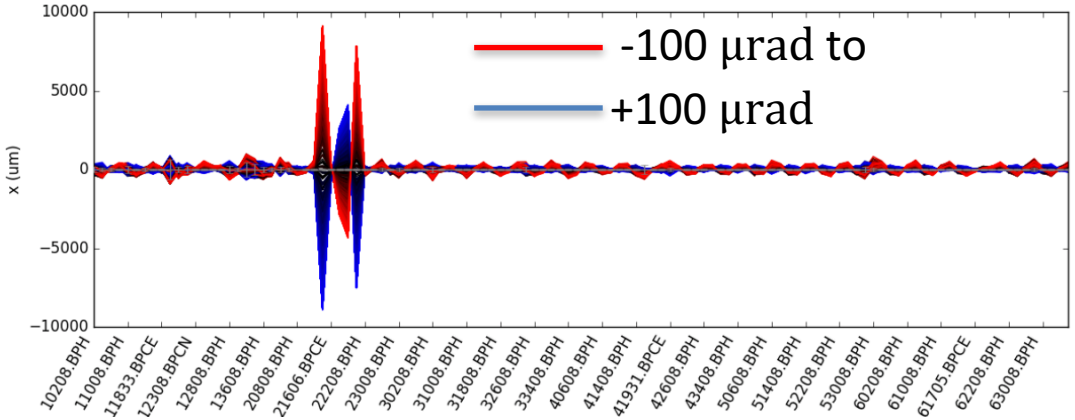
# Orthogonal bumps

- Orthogonal X and PX knobs (move only X or only PX at upstream end of ZS) are superimposed onto the extraction bump knob:
- They are time dependent: moving over the spill 1 – 5 seconds
  - An example bumper current, two opposite trims $\pm 100$ µrad made on sequential cycles as tested on 4th October:



# Summary of first validation MD

- With ZS safely retracted and extraction elements OFF, RF ON:
- Without beam:
  - Checked bumper currents followed reference as a function of time
- With beam:
  - Checked software interlocks on knobs
  - Checked closure of each orthogonal knob




  - Checked tune shift as function of knob amplitude and time dependence
  - Superimposed orthogonal knob with an extraction bump at 50%

# MD procedure at <3E11 ppp

- ZS retracted = 98 mm
  - **Without beam, set and validate nominal extraction and orthogonal knob interlocks**
  - With beam, set-up cycle with extraction sextuples OFF and with RF ON, dumping internally at end of the flat-top.
  - Repeat BPM and tune measurements as function of cycle time and orthogonal knob amplitude applied together with the nominal LSS2 extraction bump ON (i.e. at 100% amplitude):
    - Orthogonal bump knobs applied independently
    - Orthogonal bump knobs applied together
- ZS inserted at nominal position = 68 mm
  - With orthogonal bumps OFF and ZS inserted to nominal operational position, set-up nominal slow-extraction, extraction sextuples ON and with RF OFF:
    - Choose between amplitude or momentum based extraction by trimming the chromaticity and QF tune function.
  - **Once nominal slow-extraction is achieved, reduce and test fast LSS2 BLM interlock thresholds.**
  - Orthogonal knobs can now be applied.
  - Record the BLM loss distribution and beam size on grids (BSGHs) as a function of the start and end values of the orthogonal bump function, applying a linear ramp in time:
    - Work within the defined orthogonal bump limits
    - Start with angular orthogonal bumps.
    - Repeat with position bump orthogonal

# Discussion: recent comments on procedure

- *Is the SIS interlock on the dynamic bumps actually fast enough to capture an unintentionally to high bump value (as it happened in 2007)?*

  **No SIS interlocks on the extraction bumper currents the statement made in Jorg's Incident Report that they will be was never realised. This is the same of the operational beam. Before the extraction SIS checks if they bumpers are ON/OFF.**

  **We will use limits on each individual knob so that we can't put unrealistically high values. I have updated the procedure.**

- *If – after a successful MD - incorporated for continuous application, is it possible that a then non-applied applied bump could lead to an extraction issue which is worse than today's operation?*

  **In principle yes. An operational implementation at nominal intensity will need careful implementation and MP. We will not put the dynamic bump on the OP user.**

- *Should we really remove the k limits completely or only relax them according to the needs?*

  **In principle we can add wide limits bumper-by-bumper, however what is important is not the absolute value of each bumper but the relative values for each close bump applied and the resulting bump shape. We interlock on each knob applied to ensure the relative strength ratios are respected.**

- *Suggest to re-establish the situation at the end of the first part of the MD by first extractions again with a pilot beam before taking the 3 nominals. This may also help to set appropriate BLM thresholds.*

  **We will set-up anyway with the lowest intensity available, 2E11 ppp… we can't go lower than this.**