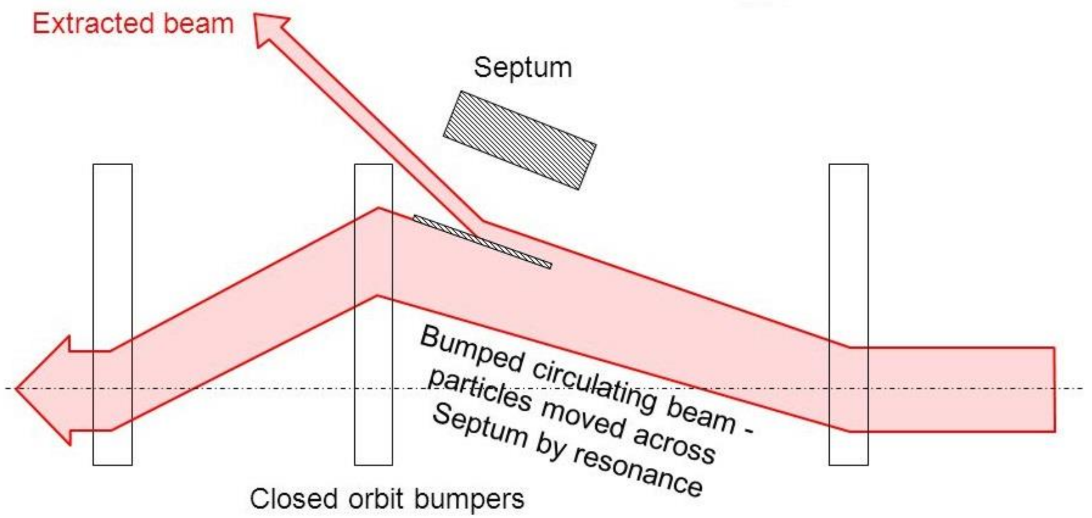
Studying the effect of massless septa on the SPS slow extraction

Kristóf Brunner

Supervisor: Christoph Wiesner

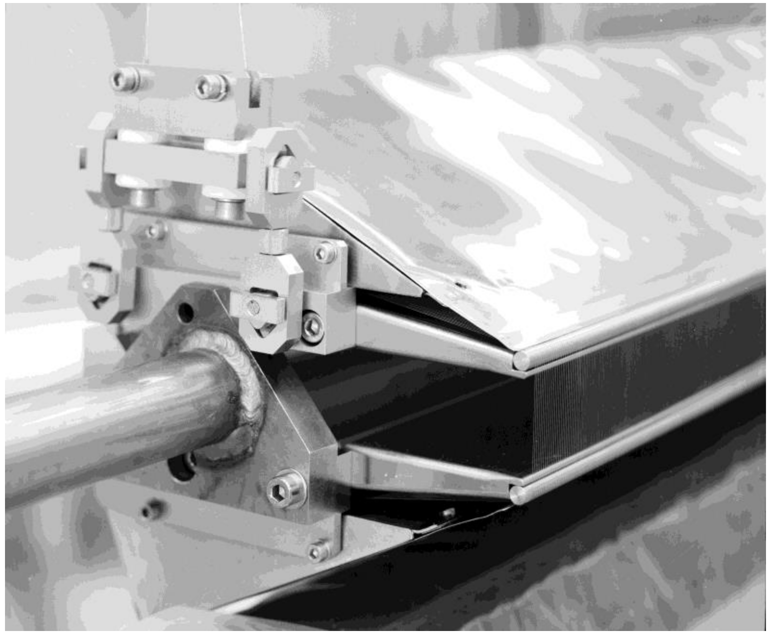
What is slow extraction and why is it important?

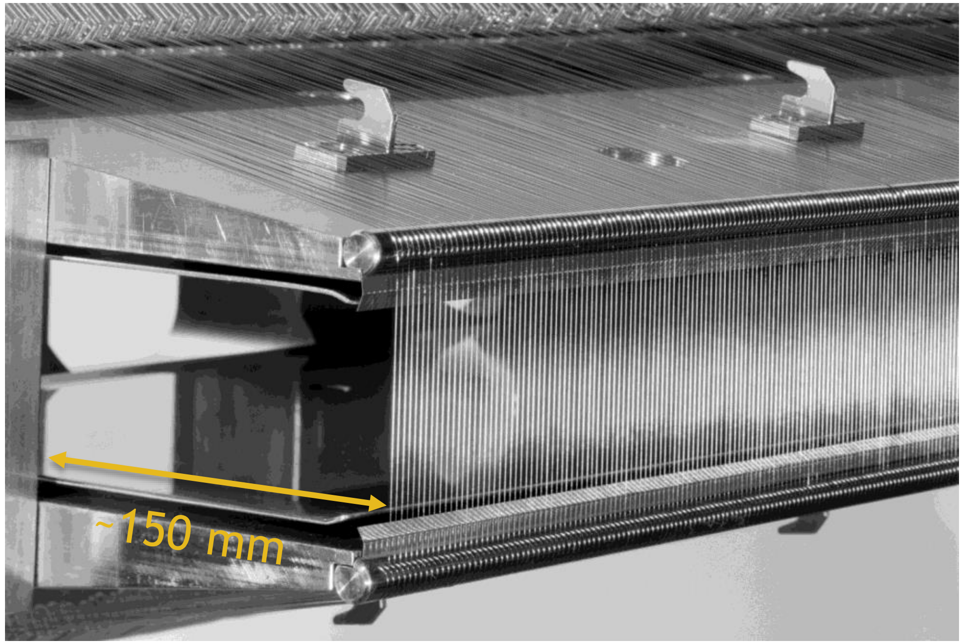
- The SPS provides beam to the fixed target experiments located in the Northern Area
- The outgoing beam has to be semi-continuous and not just a short pulse
  - The present setup is able to provide beam for 4,2 seconds (~10^6 turns)
- When the particles reach a certain distance they are extracted by the ZS electrostatic septum



[1]

The ZS electrostatic septum



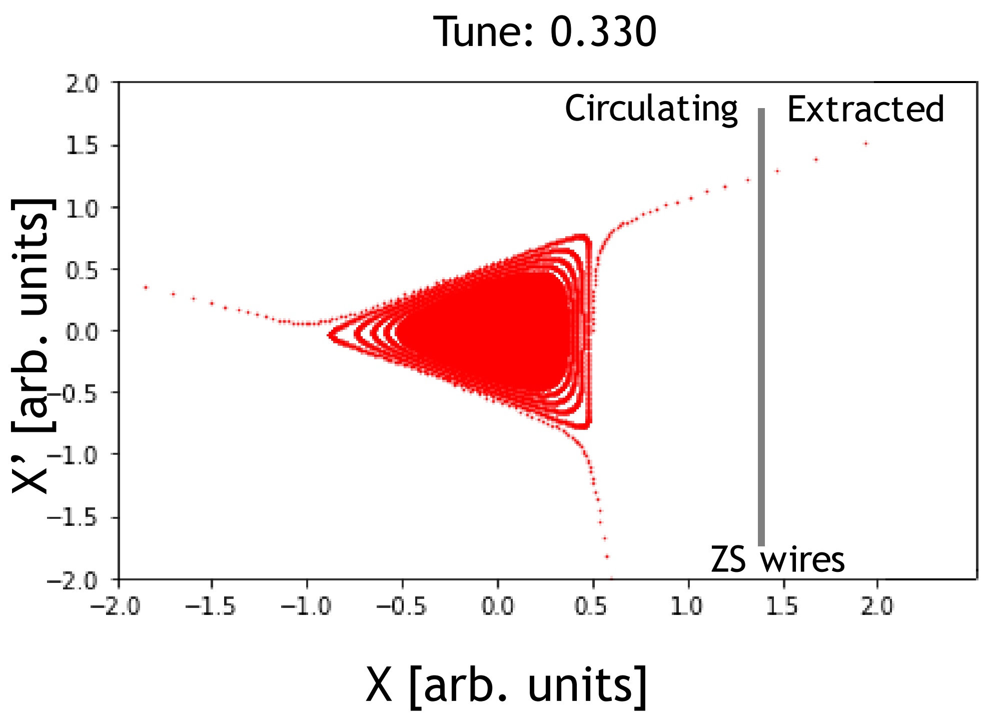


Parameters

- Wire thickness: 60-100 μm
- Total length: ~20 m
- Stable beam position: -68 mm
- Bumped beam position: -25 mm
- Wires-cathode distance: 20 mm

Third order resonance

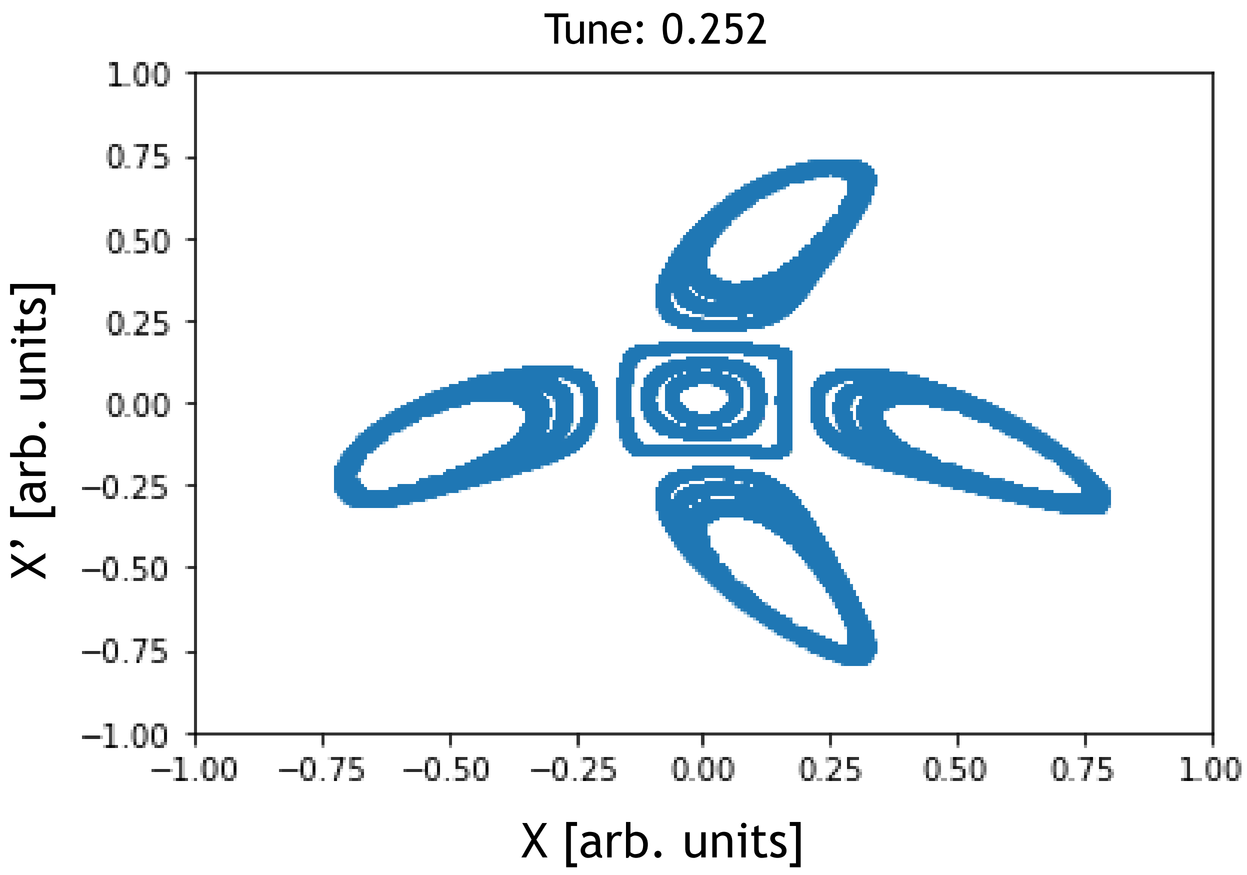
- Third-order resonance is used to drive a small portion of the particles far from the ideal beamline
  - If the tune (q) equals one third of an integer, the sextupole magnets make the particles outside of a separatrix (triangle) unstable and got extracted



Simulation

- During the summer student project, a particle tracking routine was developed in python
  - Any kind of multipole magnet (quadrupole, sextupole, octupole) are implemented as thin lens
  - The ZS septum is extracting the particles if they are in the extraction region, or register a hit of the wires or the cathode
  - The drift of particles in the normalized phase space is just a rotation
- In the simulation a series (several thousand steps) of sextupole magnet kicks and drifts were used, to get the particles' position and momentum in the phase space for different tunes

Example of different resonances simulated with the program



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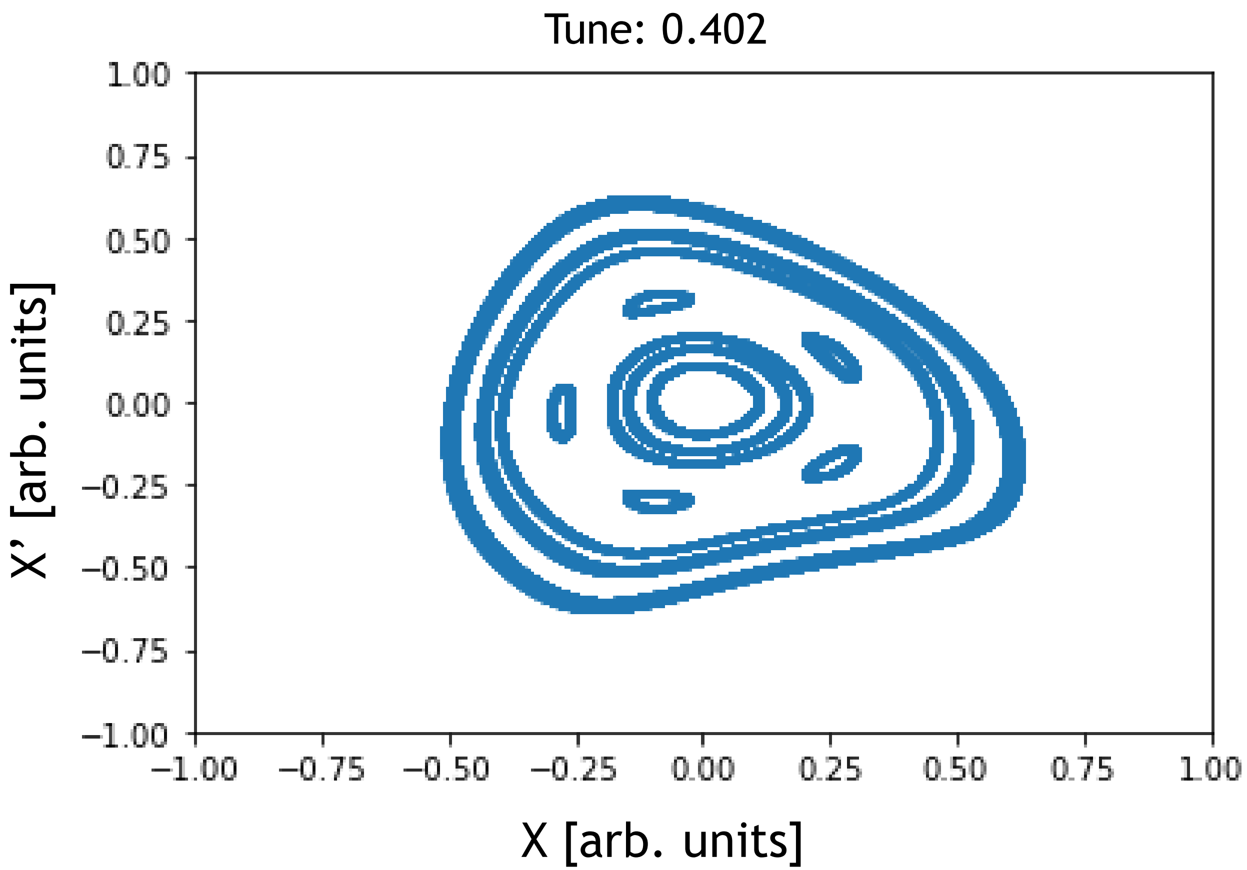

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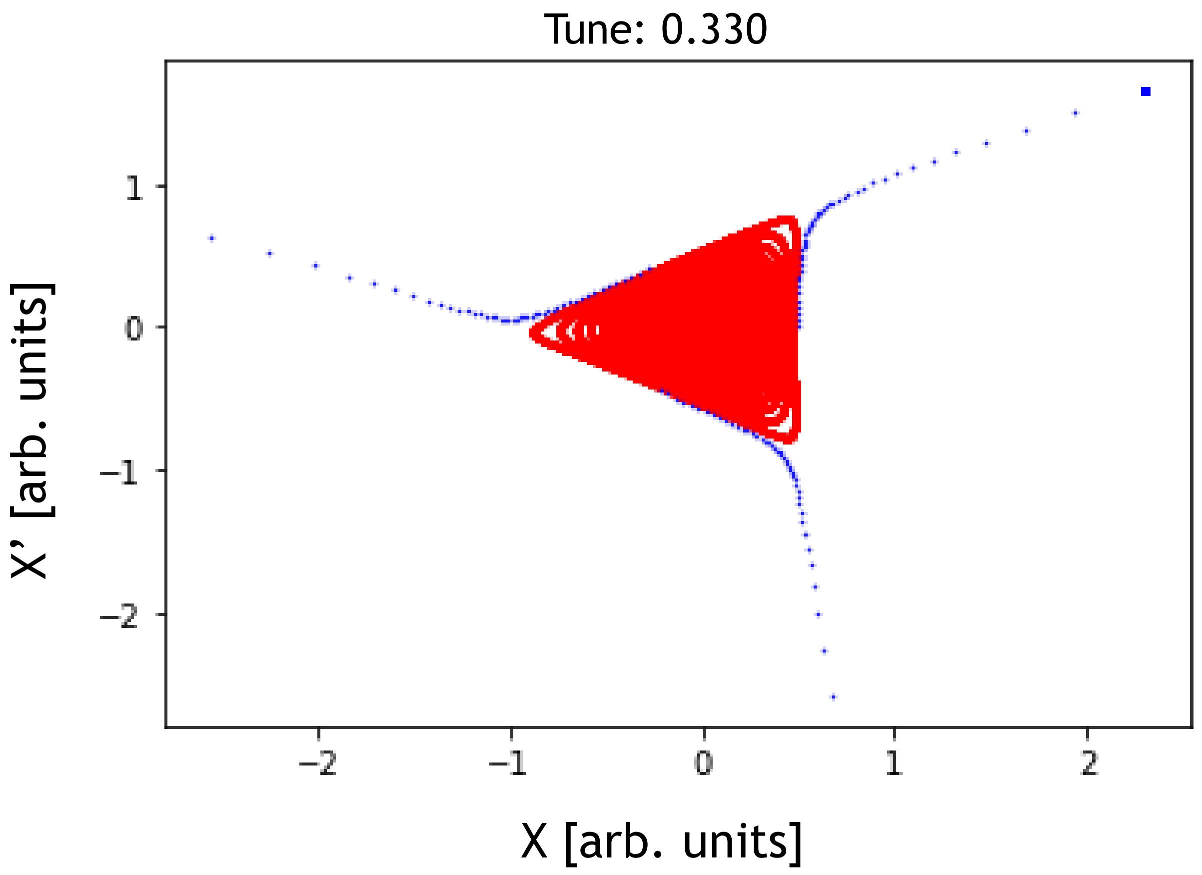
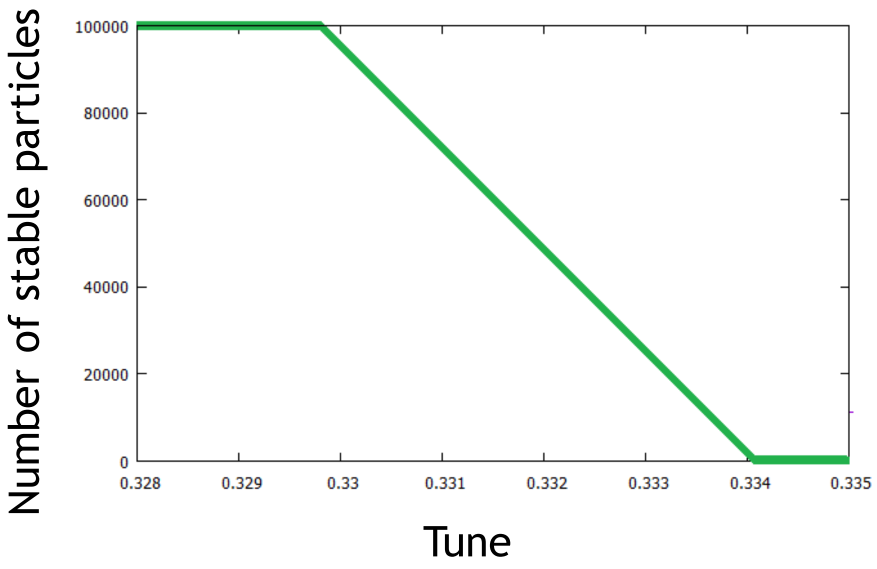


Simulation

- The tune can also be changed with every turn, this way the separatrix getting smaller and smaller (if we go closer to one third of an integer)
- In an ideal case the rate of the extraction is constant, so the number of particles should decrease linearly, and go to 0



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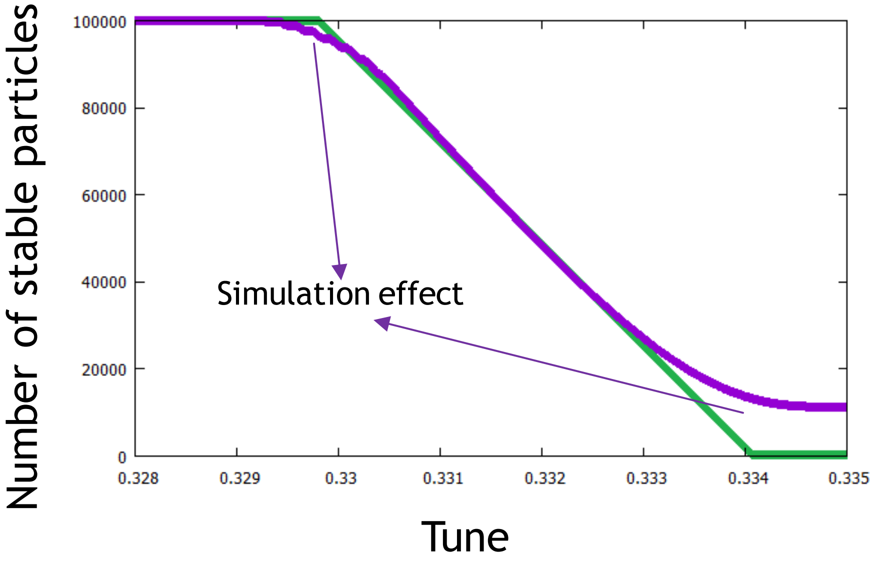
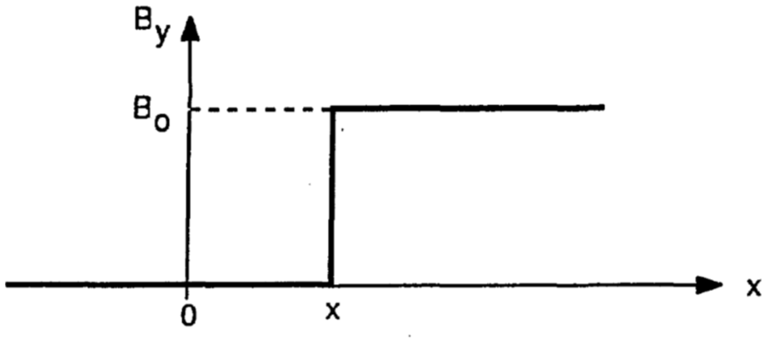
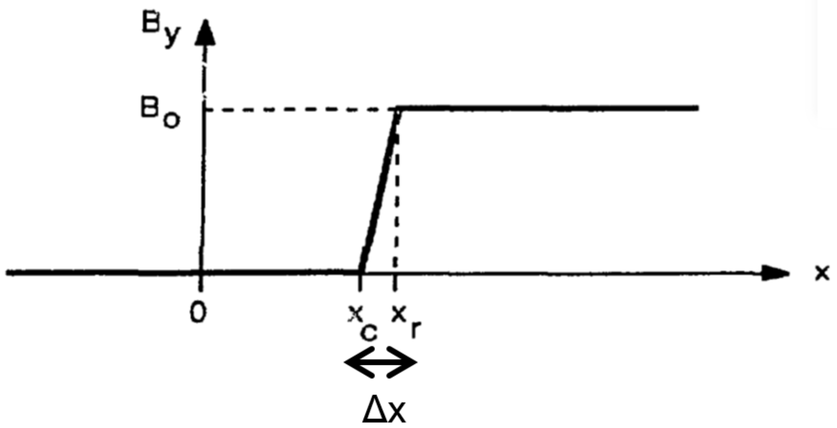


What is a massless septum?

- A septum is a device that provides homogeneous field at some region, and zero field in some other region
- It is called massless if there is no physical separator between the two regions
- The field of an ideal, and a (bit) more realistic massless septum:



Ideal field

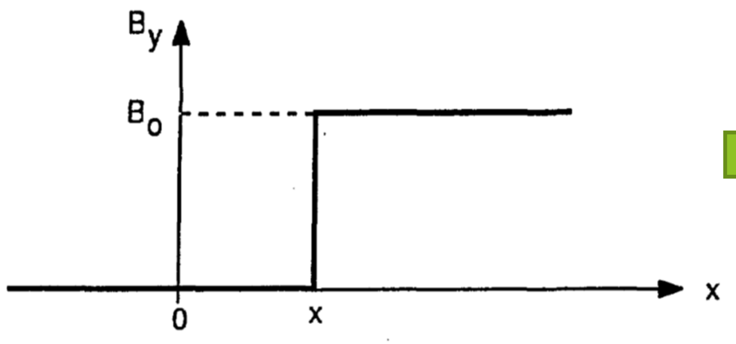


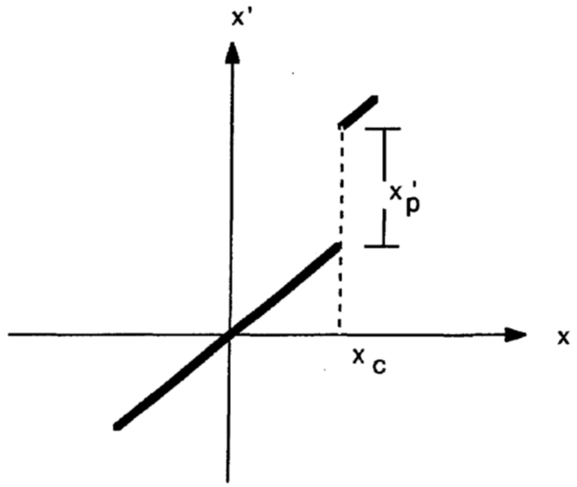
“Realistic” field

[3]

Effect of a massless septum

- In the code the massless septum is implemented as thin lens with strength dependant only on the position of the incoming particle
- This would cause a kick to the particle's momentum (x') but does not change the position (x)





Ideal massless septum

[3]

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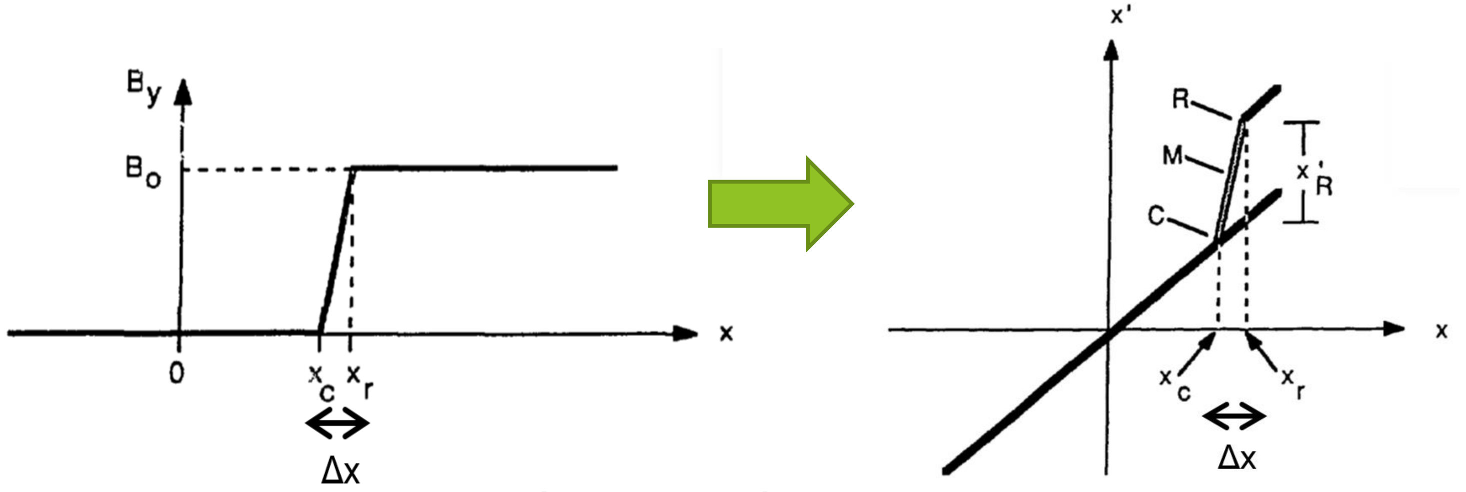
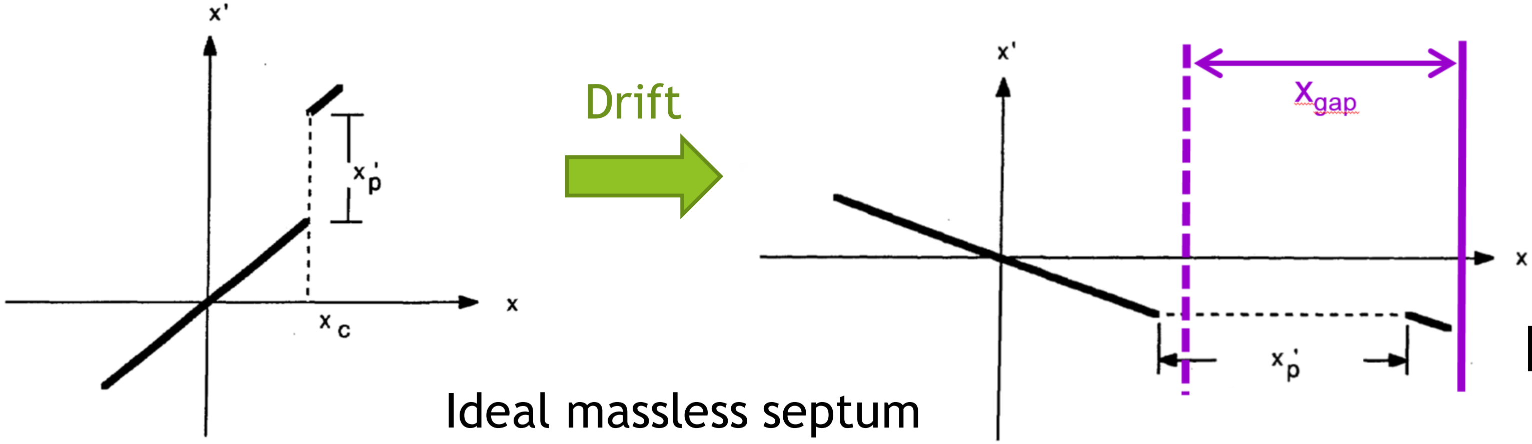


Realistic massless septum

[3]

Proposed solution to increase efficiency

- There are 2 main options to increase the efficiency of the slow extraction using massless septa
  - Decrease the number of particles that hit the wires
  - Increase the number of particles that got extracted with every turn
  - (or the combination of the two)
- The first idea is to use massless septum (or maybe two septa) to reduce the particle density hitting the wires



Ideal massless septum

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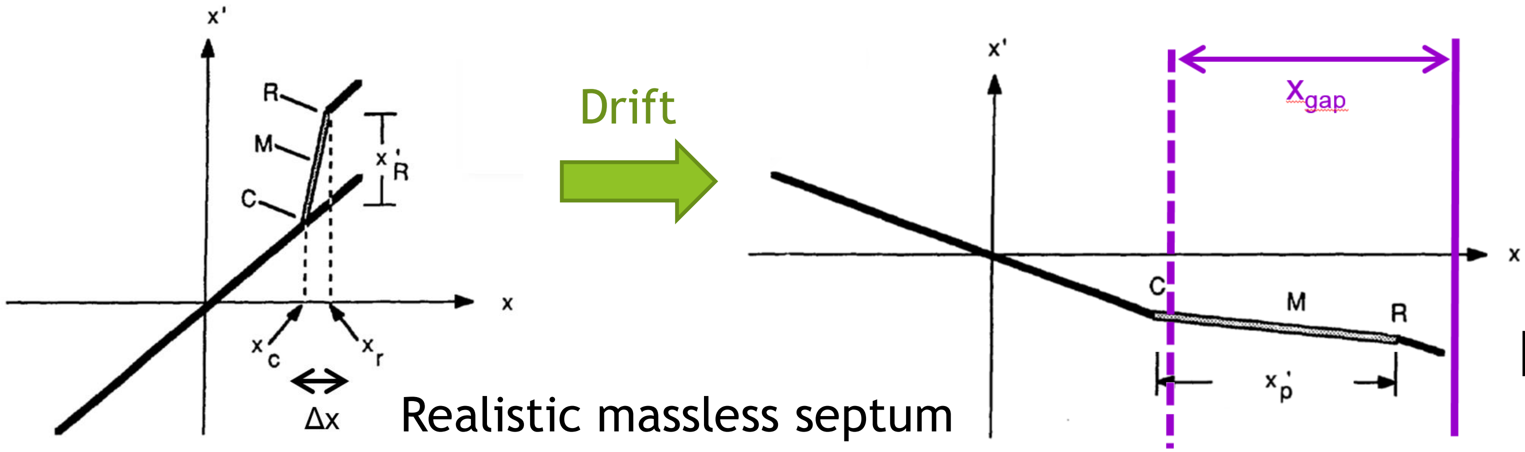
  - This solution is only feasible for very short fringe field lengths

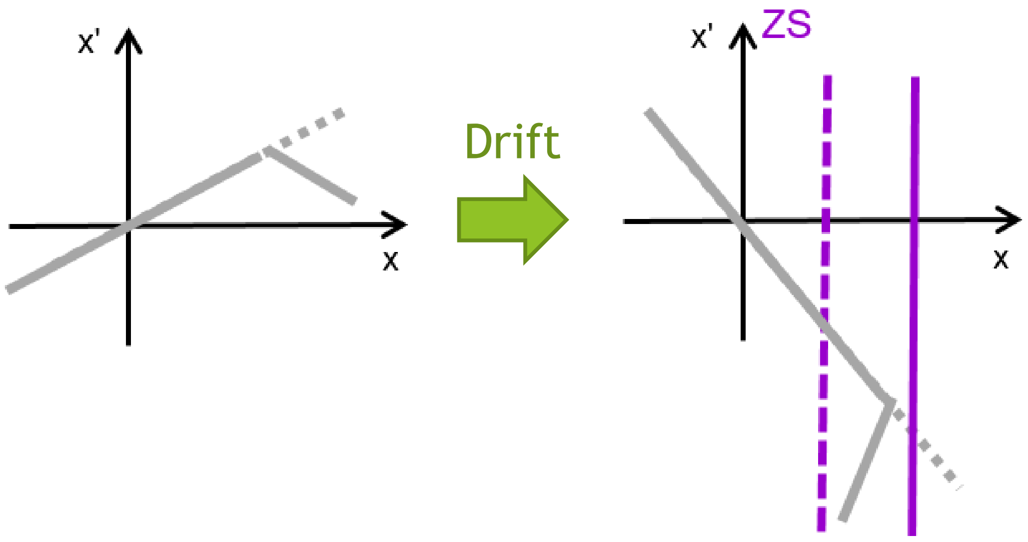


Realistic massless septum

[3]

Phase space folding

- As we discussed, it is also possible to increase efficiency by increasing the number of extracted particles, while having the same loss
  - A possible way to do so can be seen here



  - This solution uses the “fringe” field of the massless septum (it is technically easier)

Summary and outlook

- The slow extraction is a really important field of work, since it determines the efficiency of all the fixed target experiments done in the Northern Area
  - The limiting factor is the activation of the extraction region (see the presentation of Aurora Cecilia Araujo Martínez today at 10:30)
- So reducing the loss on the ZS could mean a large increase of protons-on-target for experiments in the Northern Area
  - Resulting in better statistics and more precise measurements
- The developed particle tracking code is a an easy to use, and fast way of simulating particles in the phase space
  - Multipole magnets, massless septa, drift, and extraction septa are implemented already
  - It is really easy to implement new instrumentation (for example collimator, magnetic septa)

Summary and outlook

- The code was already validated by simulating standard sextupole resonance extraction
- Novel concept of using massless septum to reduce loss during slow extraction will be tested using the developed program

Thank you for your attention!

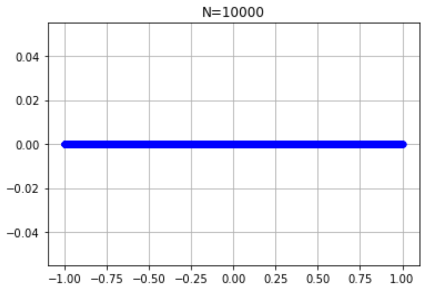
References:

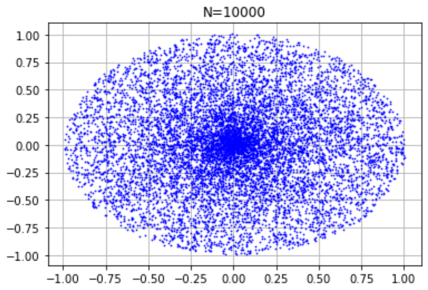
1) Matthew Fraser, CAS Budapest 2016
2) Christoph Wiesner, R&D Meeting, 08/11/2016
3) H. S. Butler/H. A. Thiessen, Proc. of the Advanced Hadron Facility Accelerator Design Workshop, 1988
4) Y. Yonemura et al., Beam Extraction of the POP FFAG with a massless septum, IPAC'03

Additional slides

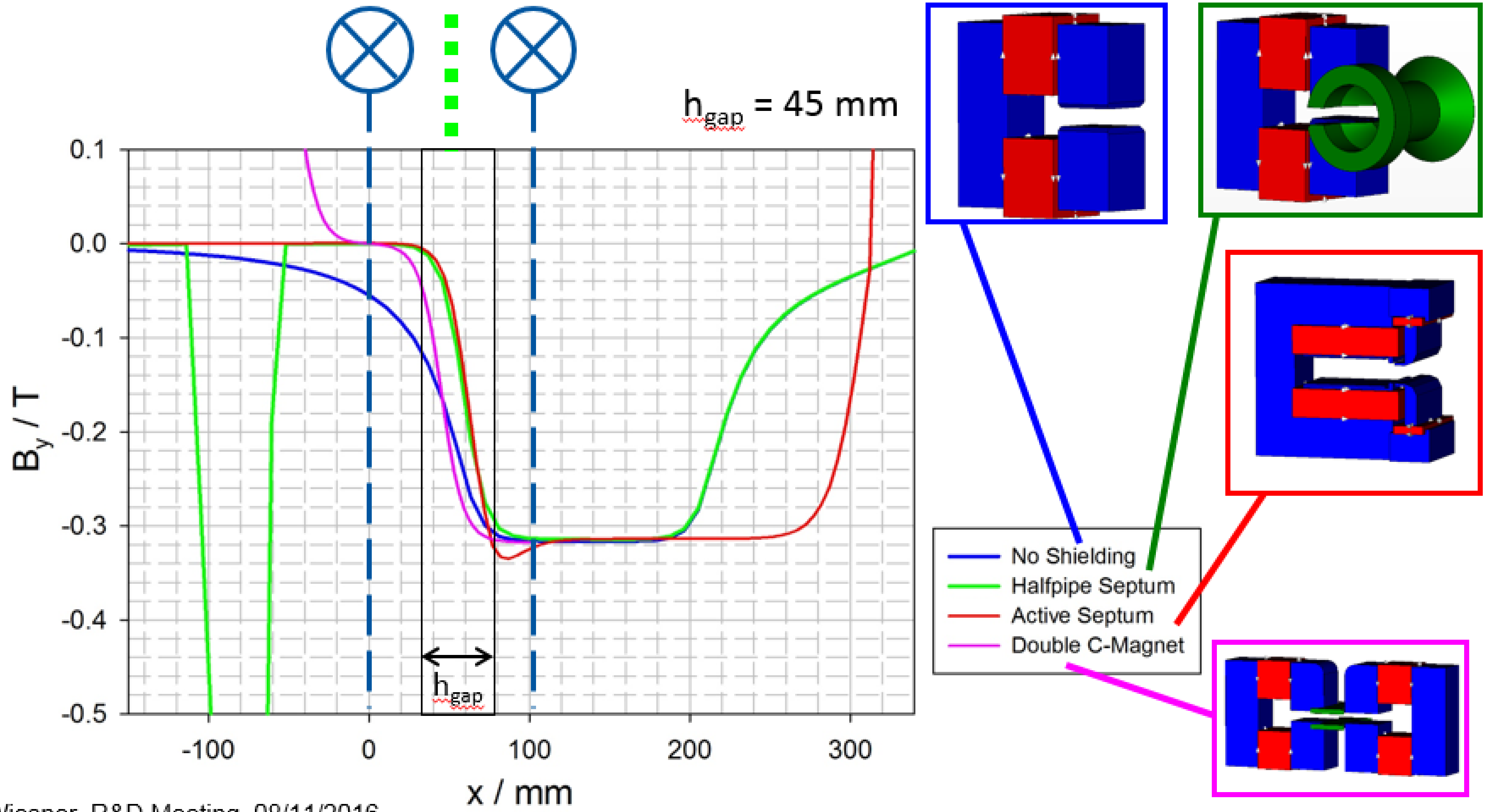
How we get a continuous extraction?

- We change the tune continuously and close in on (J-PARC) , or go through (SPS) the i/3 value (i is any positive integer)
  - This way we reduce the size of the separatrix continuously, resulting in the desired slow extraction
- The goal is to have a linear decrease of the number of particles inside the ring
- If the particle distribution is not uniform in sqrt(x^2+x'^2) then we can compensate for it by a non-constant rate of changing the tune
- Examples where a constant rate of change results in constant extraction rate:





Different massless septa and their field

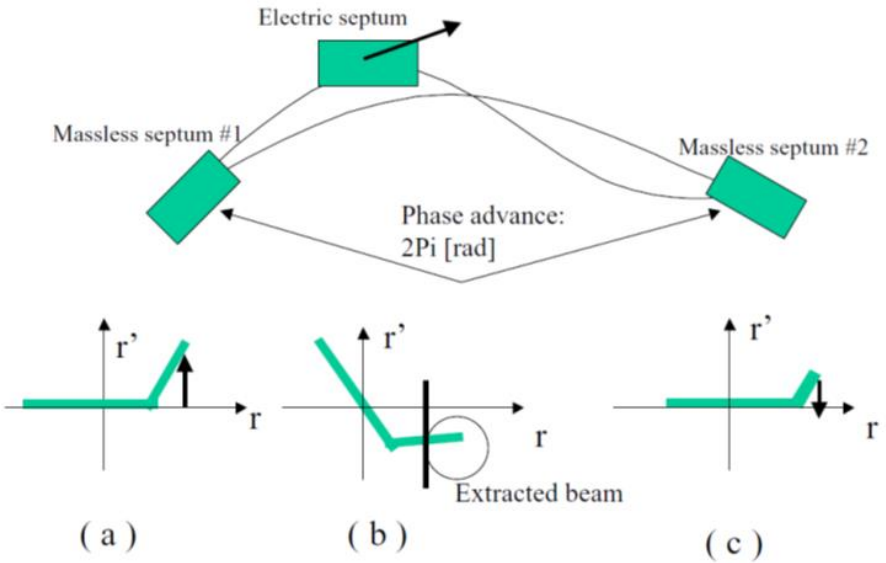


C. Wiesner, R&D Meeting, 08/11/2016

[2]

Secondary massless septum

- If the position of the ZS wires aren't perfect, then there is some of the stretched part remaining in the ring
  - To clear it we can have a secondary massless septum, identical to the first but with opposite polarization, so it pushes the particles from the stretched area back to the original shape



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