Sloex Lab for graphical representations of slow extraction

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IFAST-REX Collaboration Meeting

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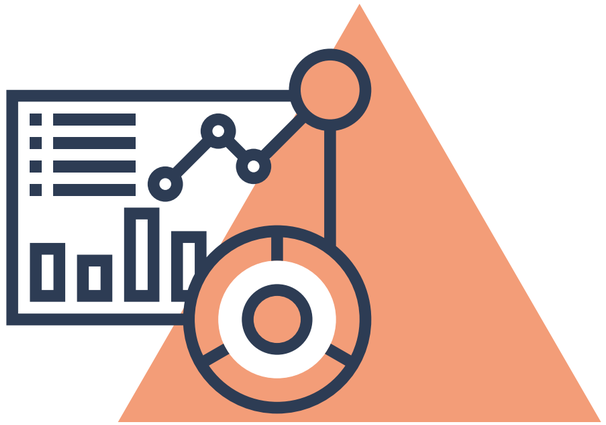
Please see Slow Extraction Workshop contributions 2022 for status + next steps of NIMMS slow extraction study https://conference-indico.kek.jp/event/163/contributions/3147/

What is Sloexlab?

A front-end interactive dashboard which connects to slow extraction python scripts for **light simulations**.



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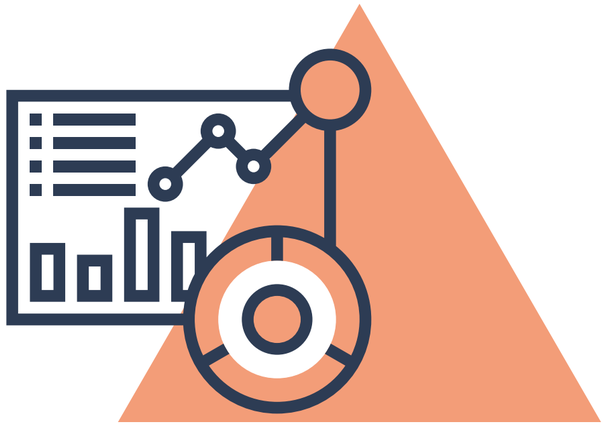

Motivations & Goals

Graphical Methods

To provide visual representations of slow extraction

User-friendly interface

To be accessible & usable without detailed python or MADX knowledge

Collaborative

To have flexible & modular tools to apply to any accelerator

Overview

- Sloexlab is written as a jupyter notebook and converted to a html web application via the viola template
  - Three main ipywidgets dashboards are written as .py files and connect to slow extraction functions.

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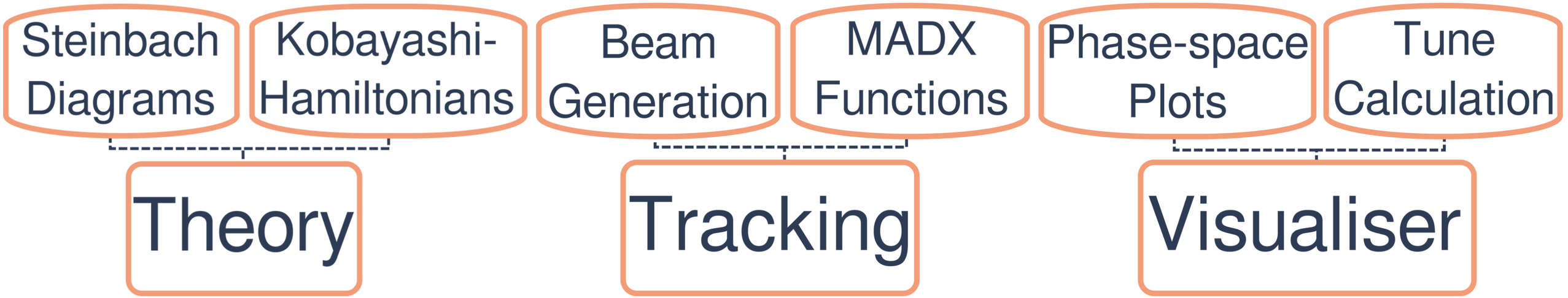

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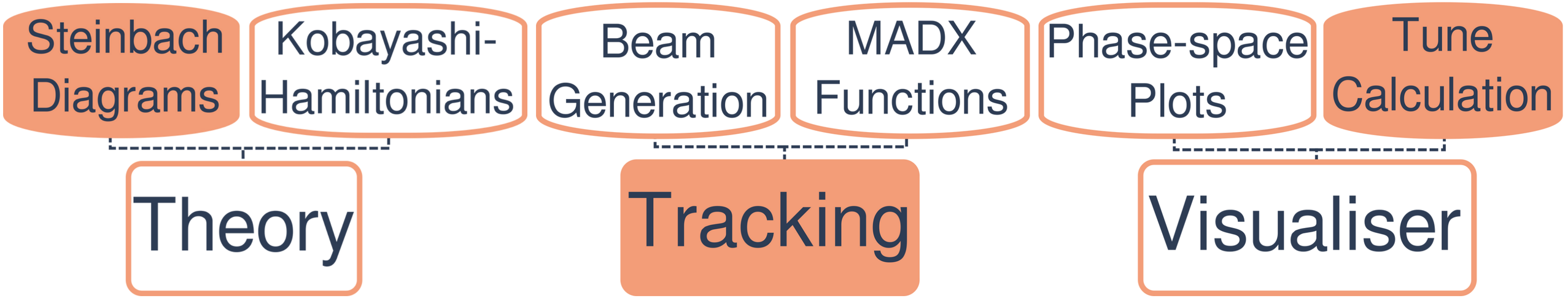


Steinbach Diagrams

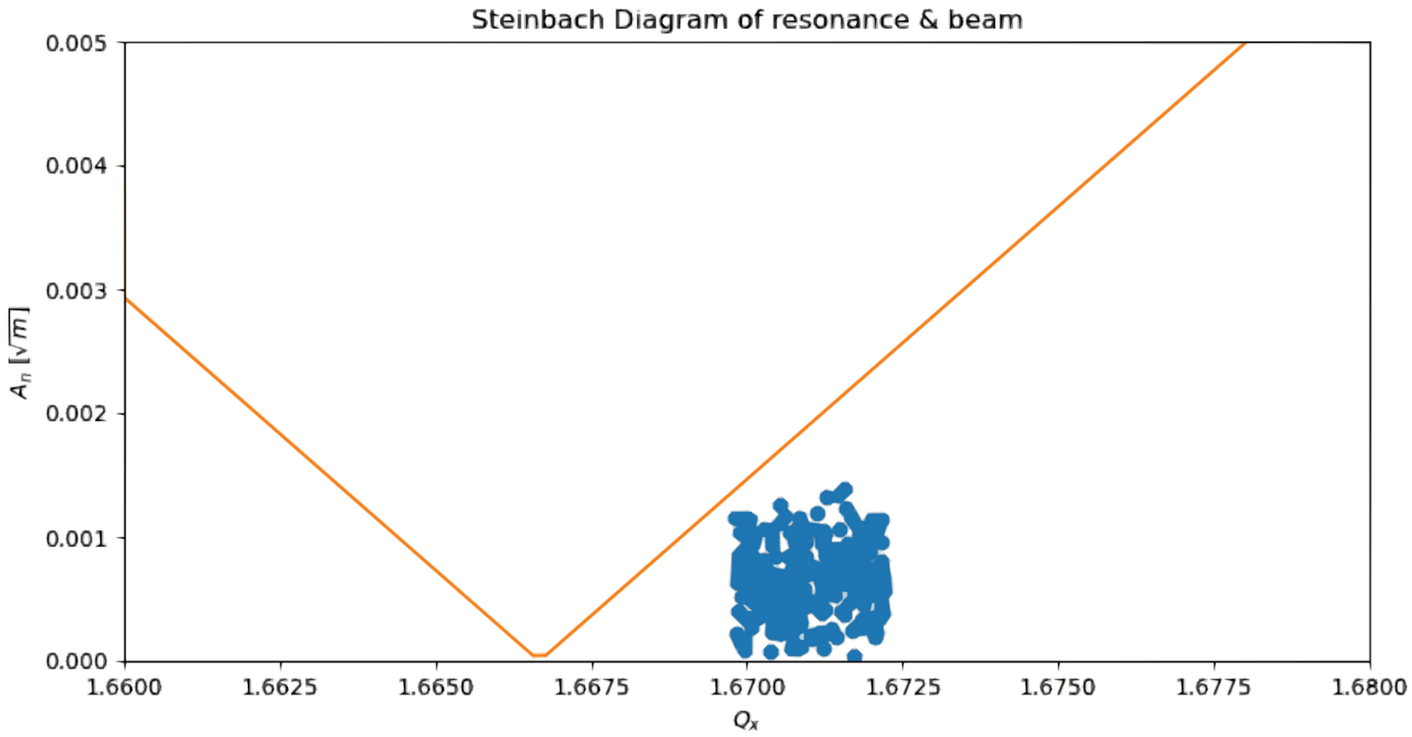
- Resonance slope determined by **stopband amplitude** width at given tune Q, depending on sextupole strength S.

$$A_{stopb} = \sqrt{48\pi\sqrt{3}\left|\frac{Q}{S}\right|}$$

- Particle amplitude given by rms emittance as a gaussian distribution

$$A_n = \sqrt{\frac{|\varepsilon_{x_n}|}{\pi}}$$

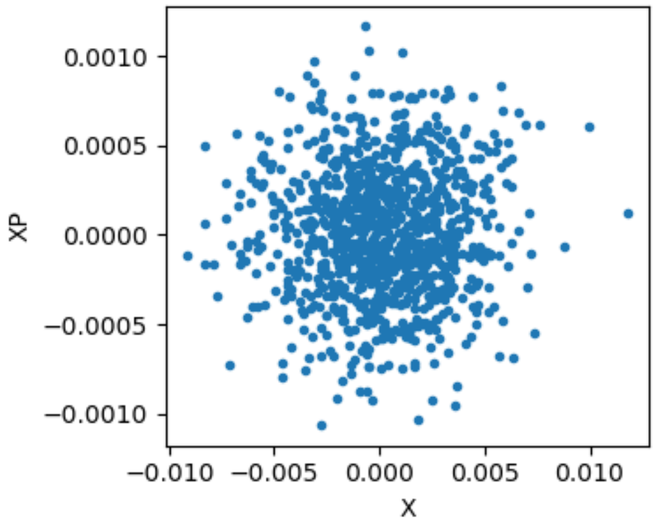
$$\varepsilon_{x_n} = \mathrm{Norm}(0, \varepsilon_{x_{\mathrm{rms}}}, N_p)$$

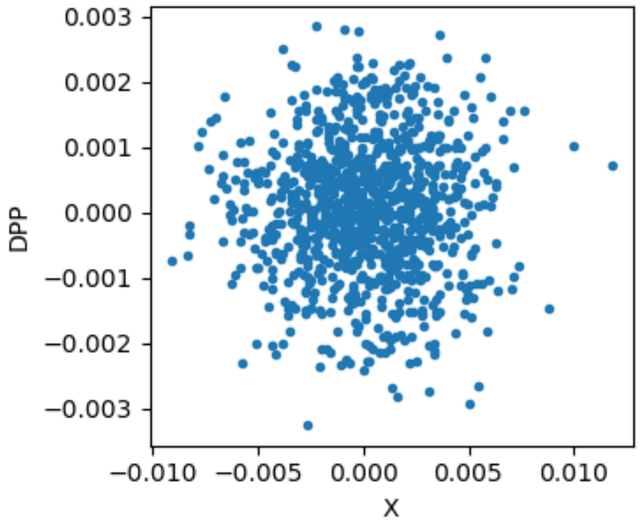


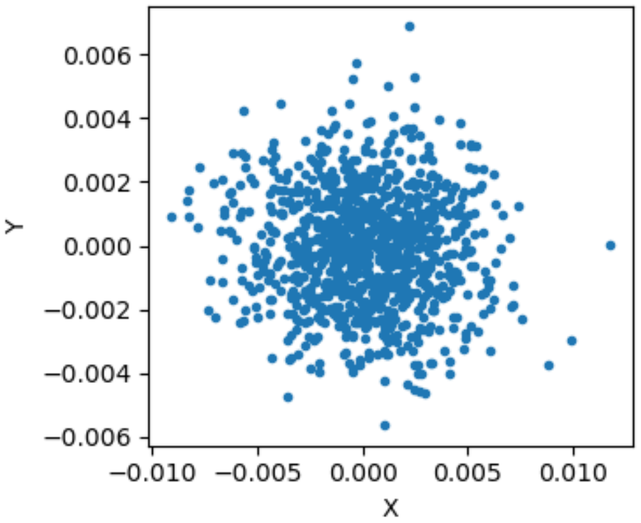
Tracking

- Produces a Gaussian beam of particles for a given Twiss optics
- Reads in a .seq file from MADX using **cpymad interface**
  - Plots twiss optics & returns dataframe file
- Currently tracks with *ptc_track* module, observing beam at a particular element
  - Returns a .txt file of 6D coordinate space

m [GeV]	11.17467		
p [GeV]	11.415636		
Np	1000		
dpp	0.001		
beta x	8.75	beta y	3.38
alpha x	-0.132	alpha y	-0.374
Disp x	0.116	Disp y	0
Disp x'	0.0104	Disp y'	0
ex	0.000001	ey	0.000001







Tune Calculations

Use of Numerical Analysis of Fundamental Frequencies (pyNAFF) to do a FFT on particle oscillation.

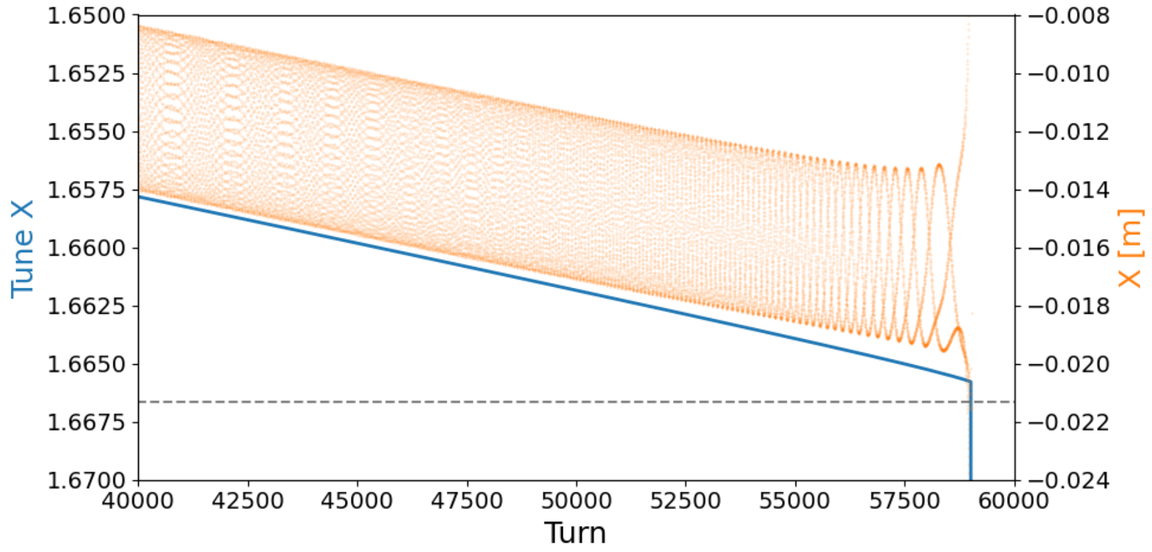
Inputs:

- Data (x or y as function of turn number)
- Total turns (window calc)

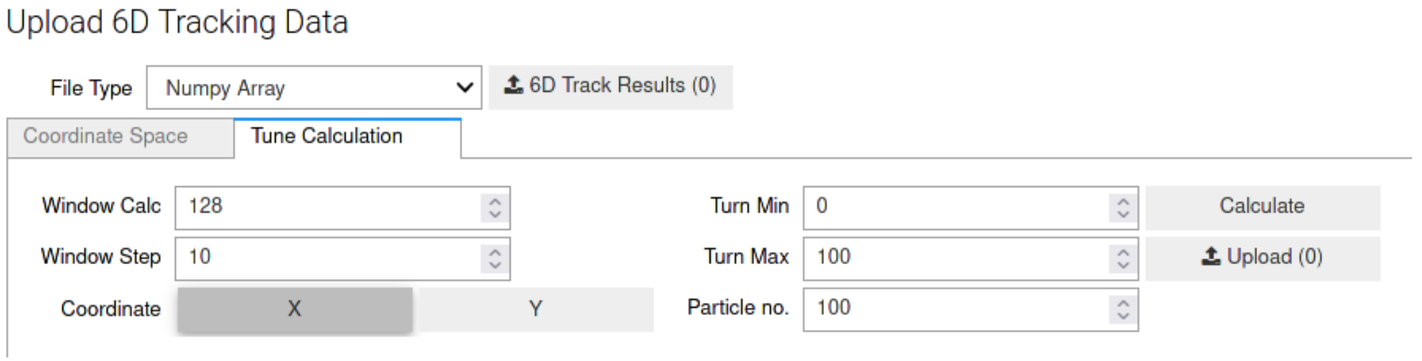
Outputs:

- Harmonic order for that window

Used for tune evolution plots.



X oscillation of 1 particle during betatron core extraction and its corresponding horizontal tune



Present Limitations

- Primarily for **light** simulations:
  - Running PTC via cpymad via sloexlab interface
  - No current options for batch running
  - Running PIMMS lattice in SWAN with 2 cores:

Turns	10	100	1000	10000
$N_p = 100$	< 1 s	2 s	20 s	235 s

- Web **upload limit** is 10 MB
  - Can be manually increased, but not designed for large file sizes
- Notebook hosted by Binder which builds from git repository into JupyterLab
  - Either wait for notebook to build, or alternatively use old link for previous builds

Action Plan

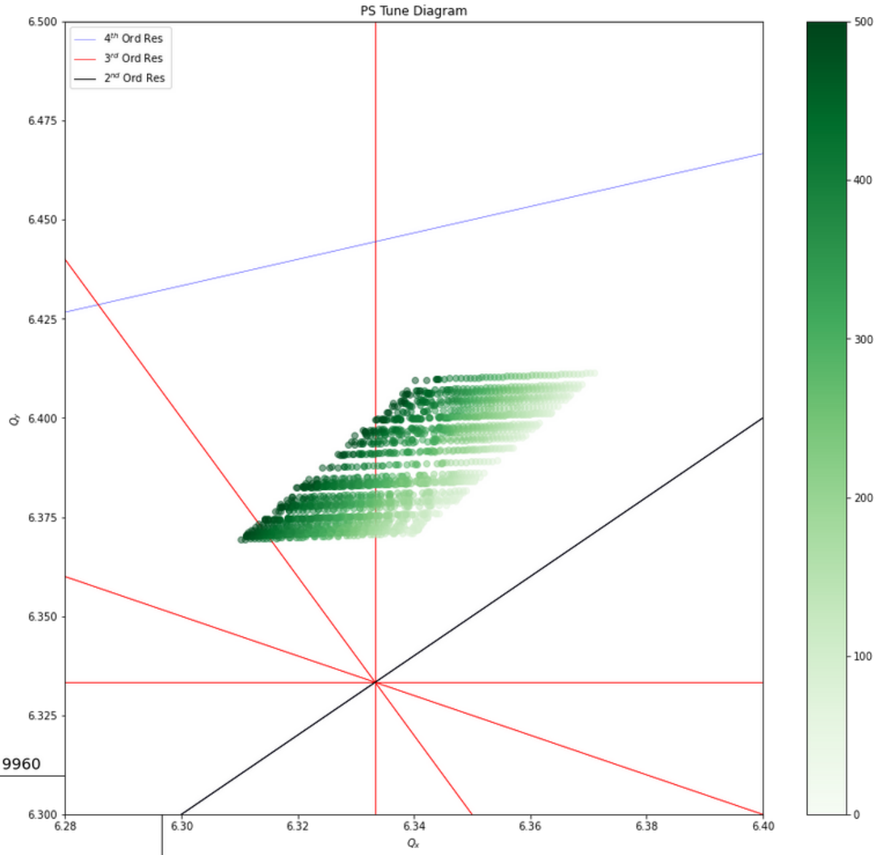
1. Develop **minimum viable product** in the form of a website. First stage of debugging, testing and feedback

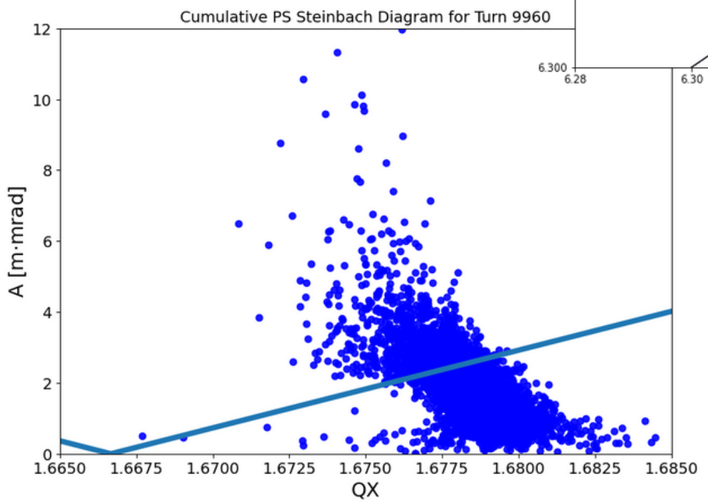
2. Add **planned features** before releasing to wider audience Ensure compatibility with different accelerators

3. Open up for user development to incorporate user-written scripts

Planned features

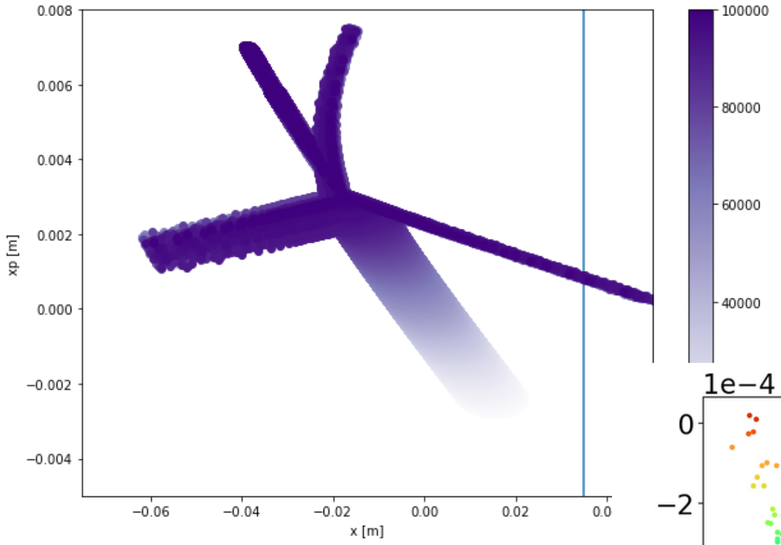
- Additional MADX & tracking flexibility
  - Choosing between MADX thin-lens or PTC
  - Vary flags for PTC universe
- More plots of tune calculation results
  - Qx-Qy resonant tune plot
  - Amplitude calculation for Steinbach plots
- Implementation of animations

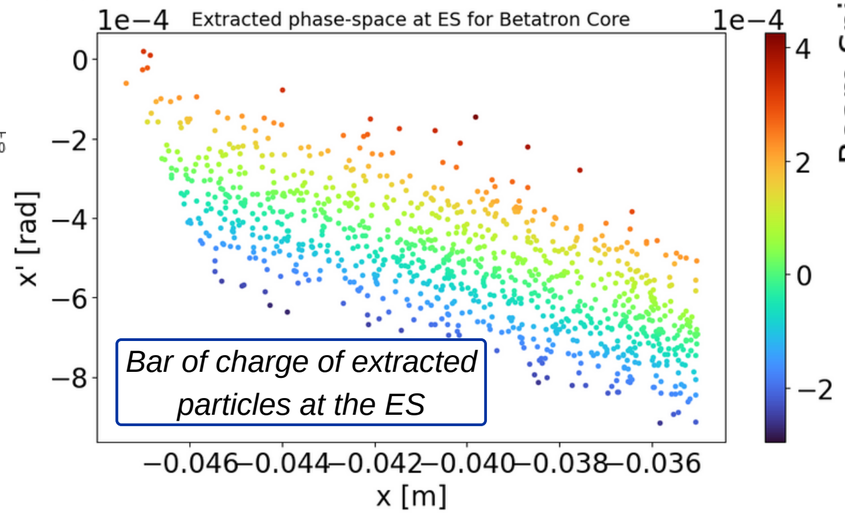


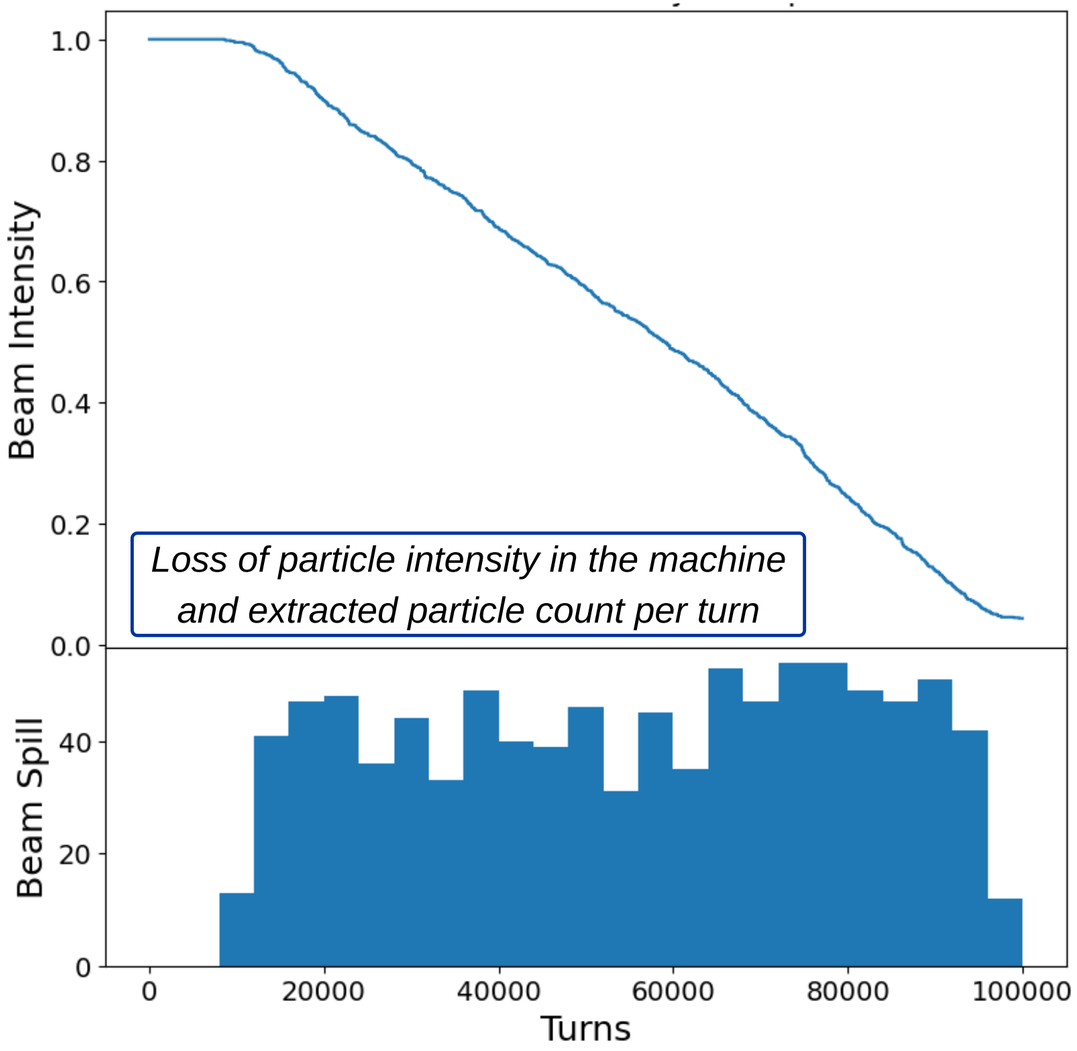


Long-term features

Betatron core simulation of PIMMS for 1000 particles during 100,000 turns







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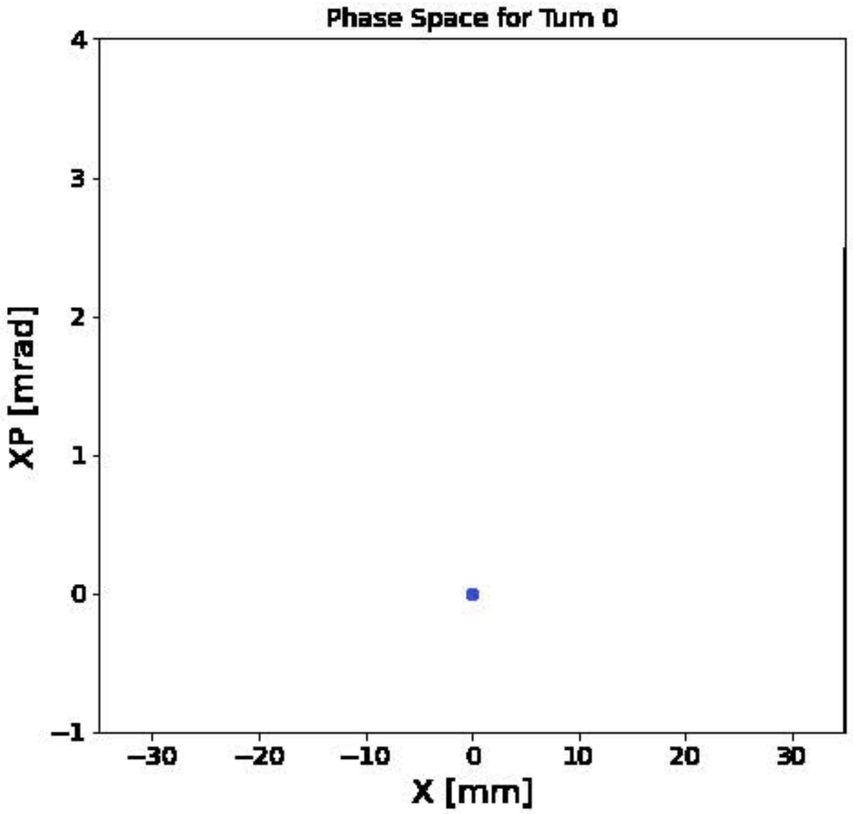

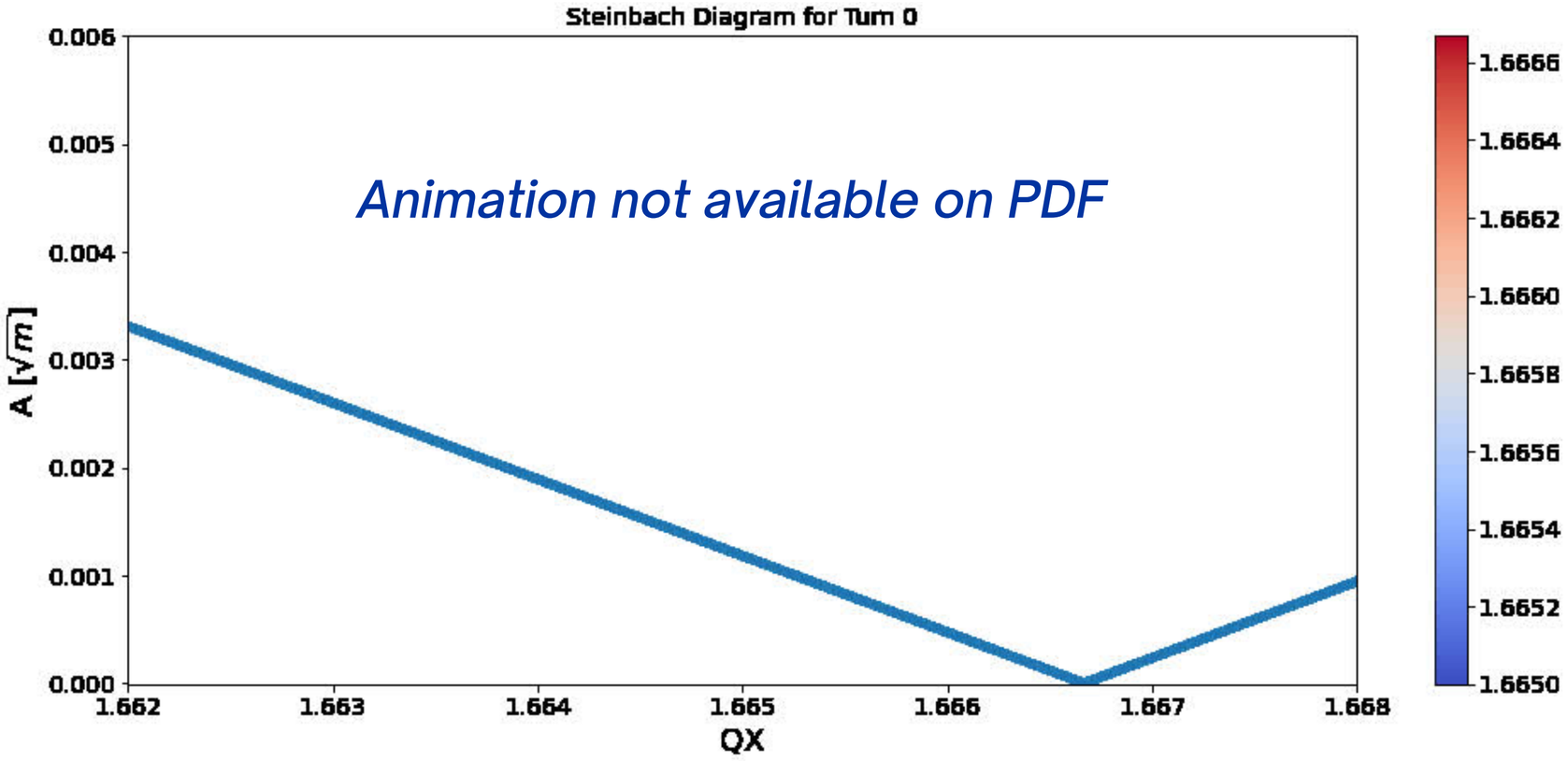

Animation not available on PDF

Collaborative Efforts

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  - Opportunities for **different approaches** to slow extraction simulations

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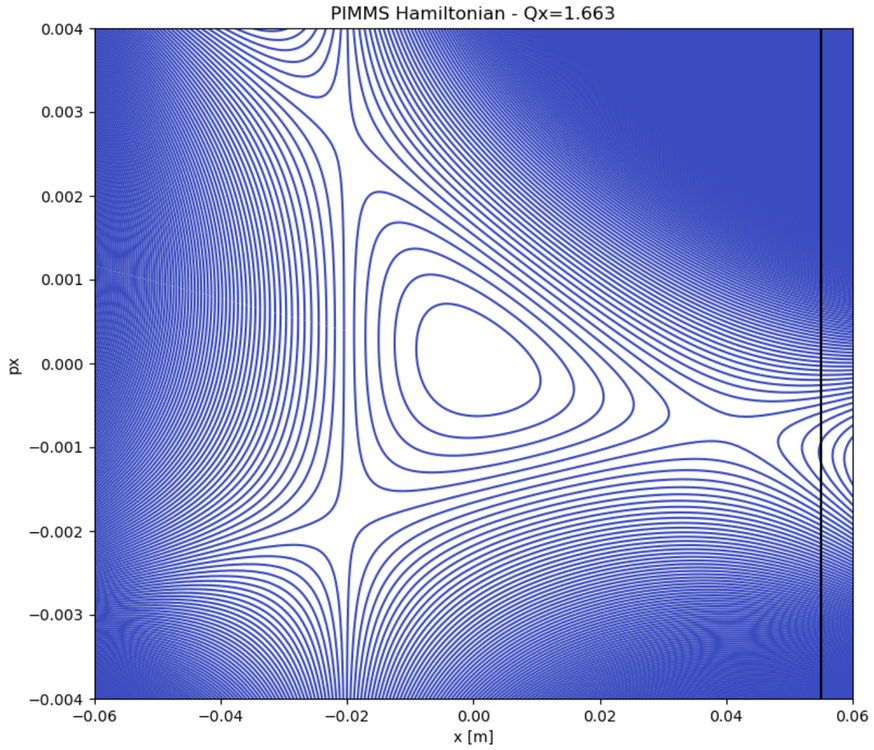
  - Calculates **Hamiltonian term** at a particular point in the synchrotron, given a Twiss dataframe as an input



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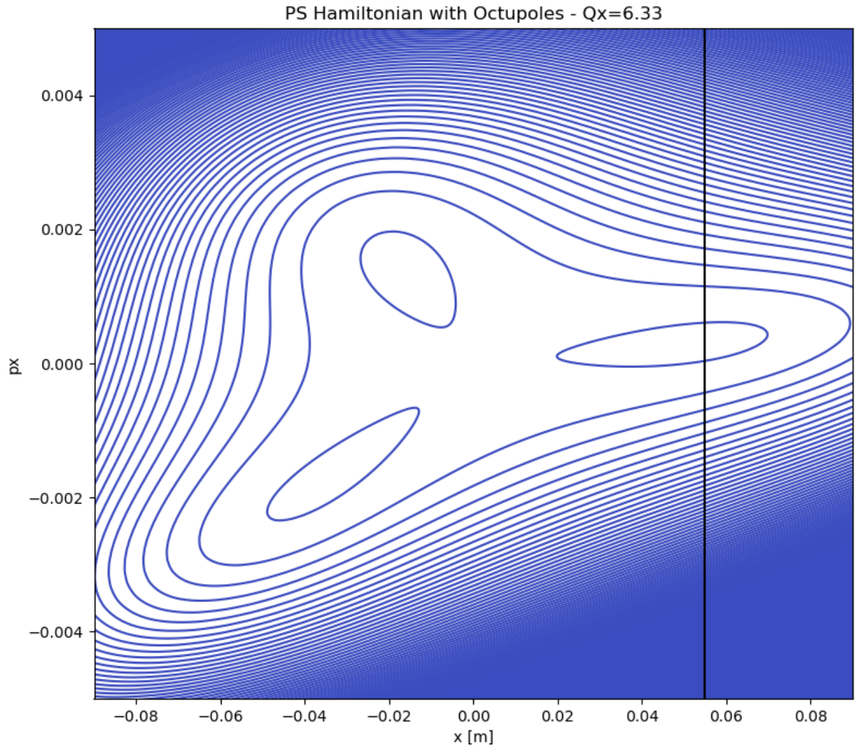

Example 2

Not yet incorporated

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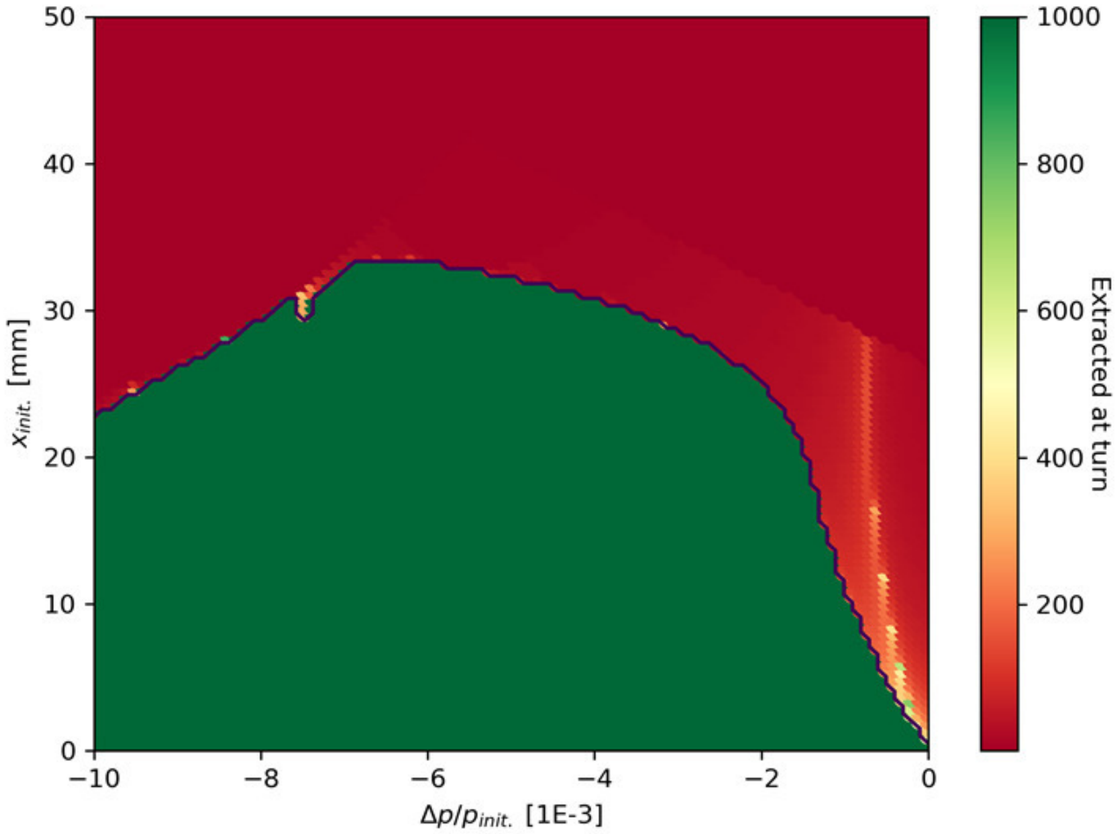
  - Defines the stable and unstable regions in tune-space



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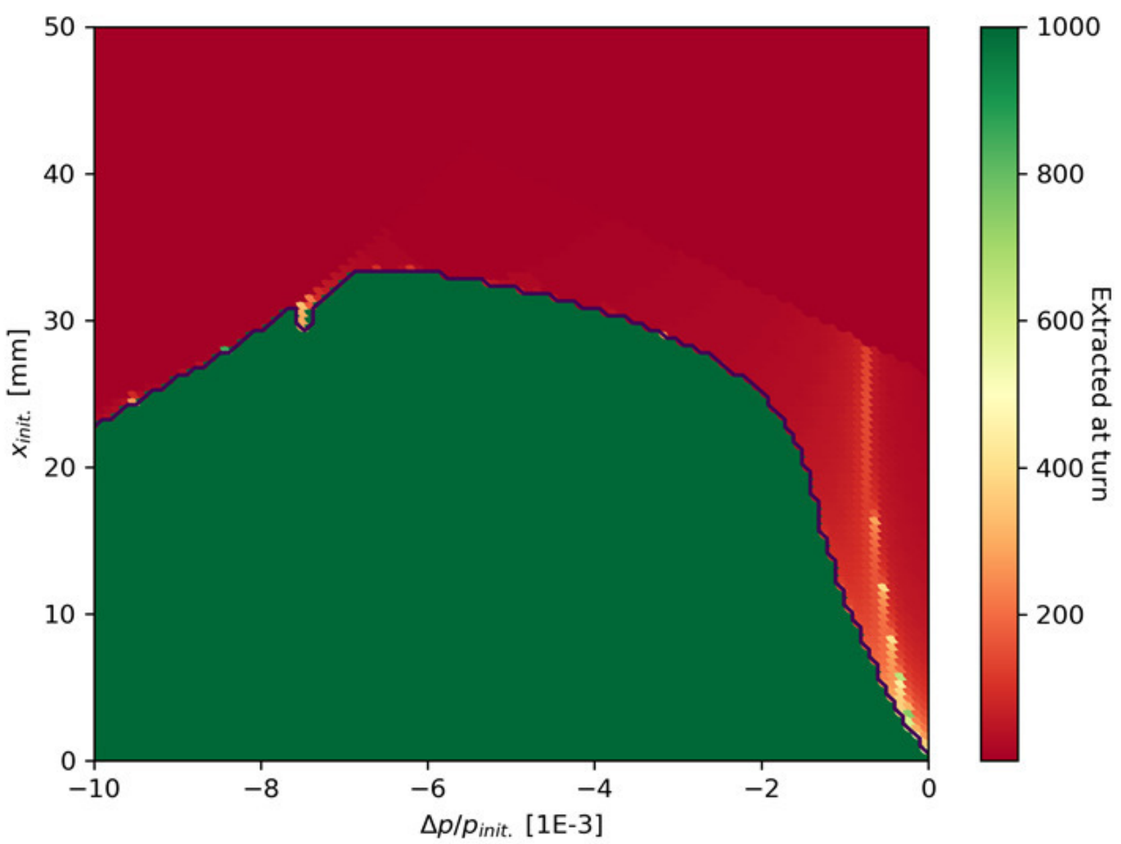

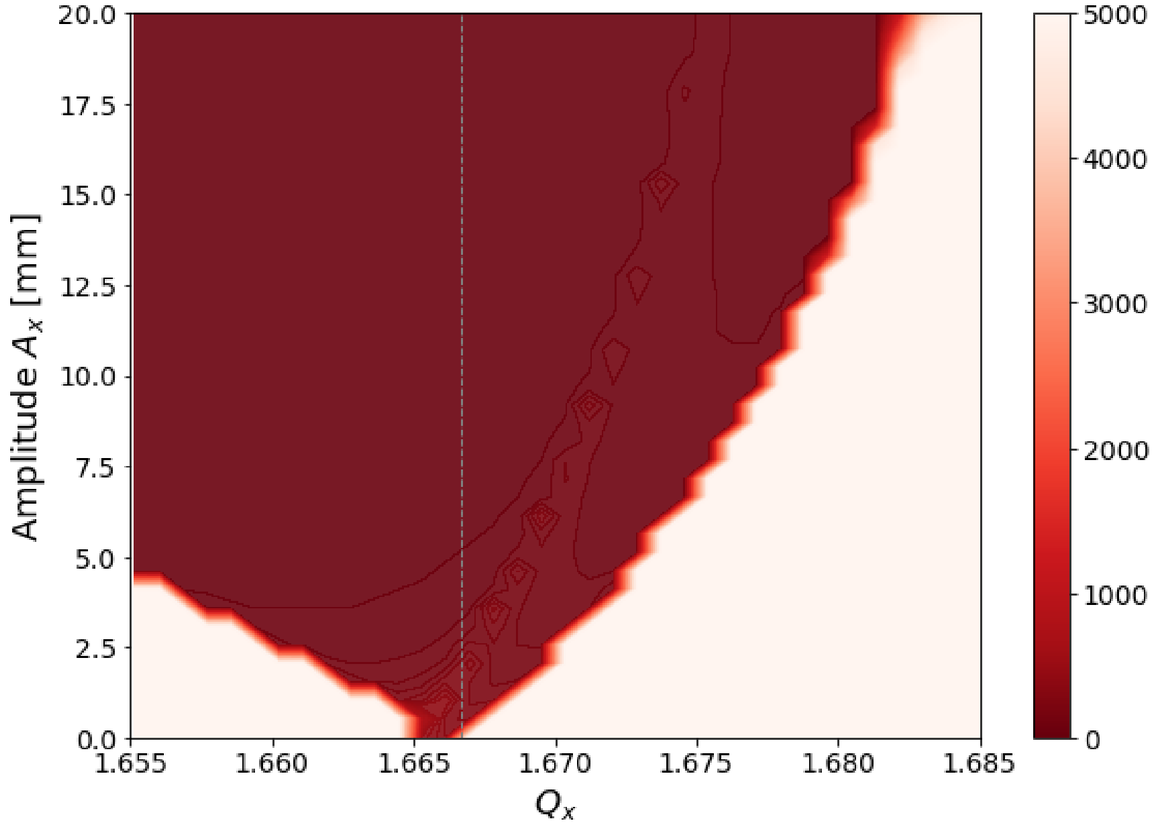

Conclusions

- Graphical tools were developed to aid the design & simulations of NIMMS slow extraction
  - Decided to incorporate these features into an interactive dashboard
  - Community interest prompted further development

- Sloexlab is in pre-alpha stages
  - Development + testing required before sharing with users

- Current focus is fast, light simulations for reference & understanding

Thank you for listening - questions welcome here or at
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