Using Online Single Particle Model for SNS Accelerator Tuning

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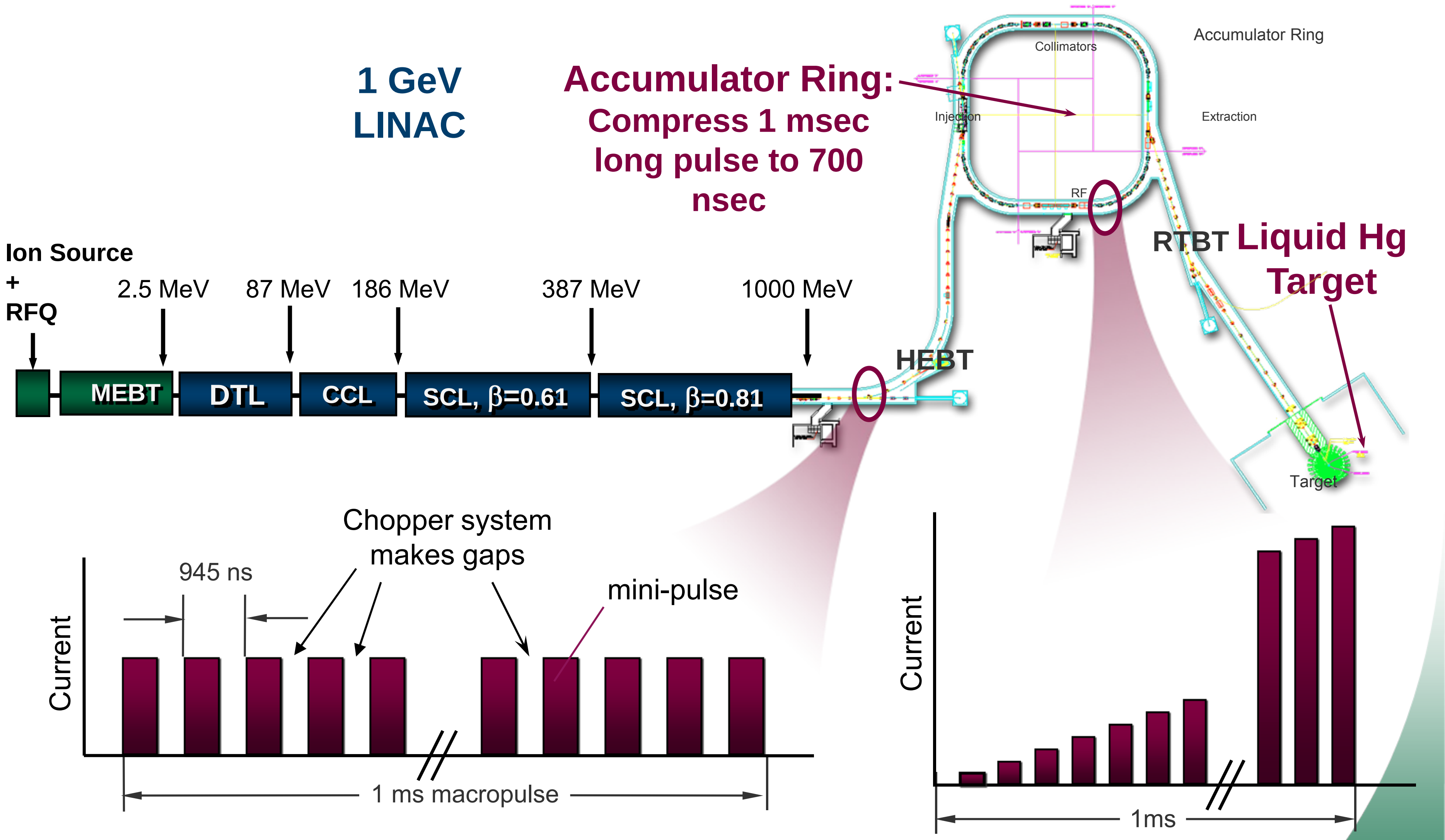
Outline

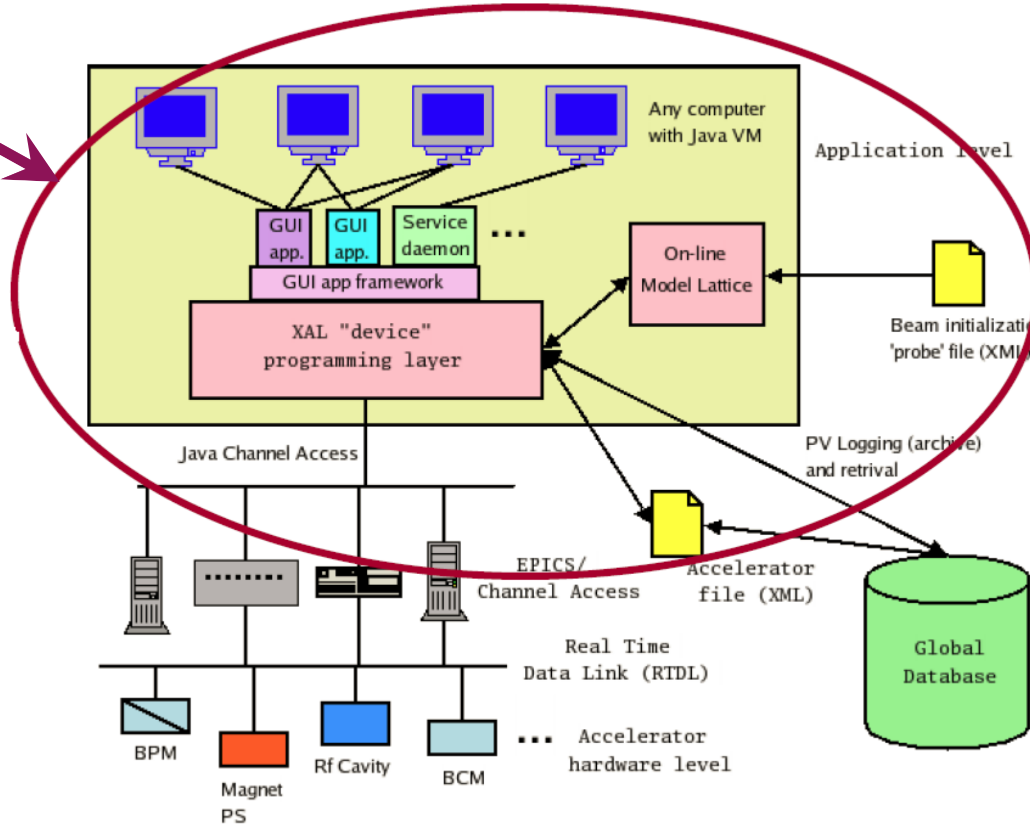
- **SNS Accelerator Complex**
- **XAL Structure and Online Model**
- **Model Based Orbit Correction**
- **Longitudinal Phase Space Tuning**
- **Conclusions**

SNS Accelerator Complex



XAL Overview

XAL and its apps



SNS application software environment for

High level physics application software for modeling, operation and accelerator physics studies

XAL includes:

- **Online Model**
- **Tool Box (math, optimization, plotting etc. packages)**
- **Application Framework**
- **Services**
- **Abstract CA Clients layer**

Models and Applications

Codes and their usage at the SNS Central Control Room (CCR)

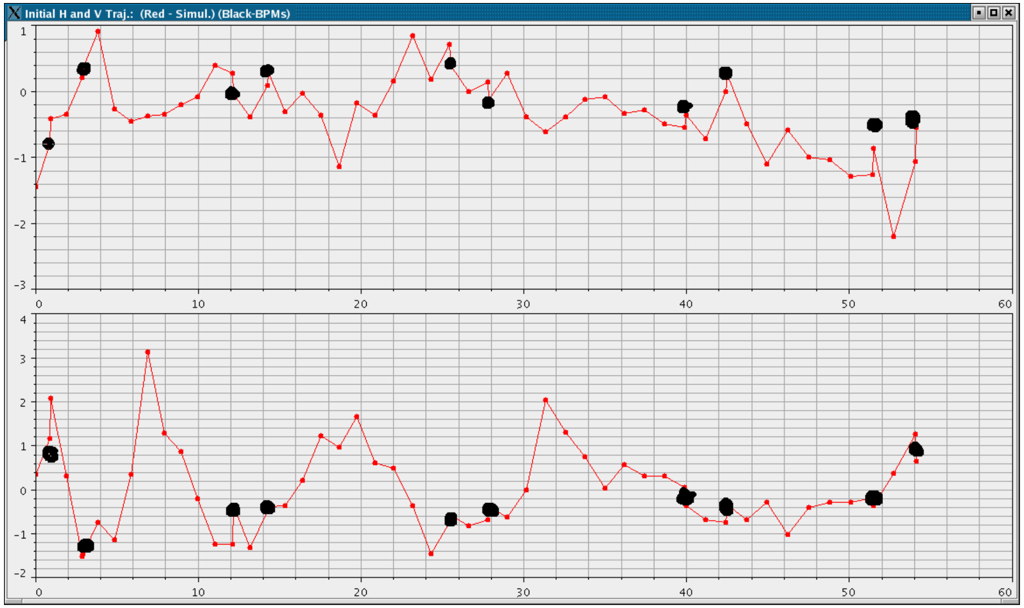
Type	Single-Particle	Envelope w/wo SC	Multi-Particles
Code	XAL Online Model Trace3D	XAL Online Model Trace3D	PARMILA IMPACT
Usage	XAL OLM: • Orbit Correction • Beam Based Orbit Correction • Model based Orbit Correction • Phase Scans and Longitudinal Tuning • Phase Tuning Control • Energy meter • Off-line analysis Trace3D: • Virtual Accelerator	XAL OLM: • Transverse matching • Virtual Accelerator Trace3D: • Off-line modeling • Virtual Accelerator	PARMILA: • Design • Transverse Matching • Off-line modeling IMPACT: • Off-line modeling

Used in SNS CCR

Combination Off-line and CCL usage

CCL Orbit Correction Problem

- **CCL has 48 quads and 10 BPMs**
- **Traditional orbit correction does work**
- **Losses and activation were high even after this orbit correction**
- **Conclusion: it is possible to have near zero BPMs signals and big bumps in the trajectory between them**



Black points are BPMs

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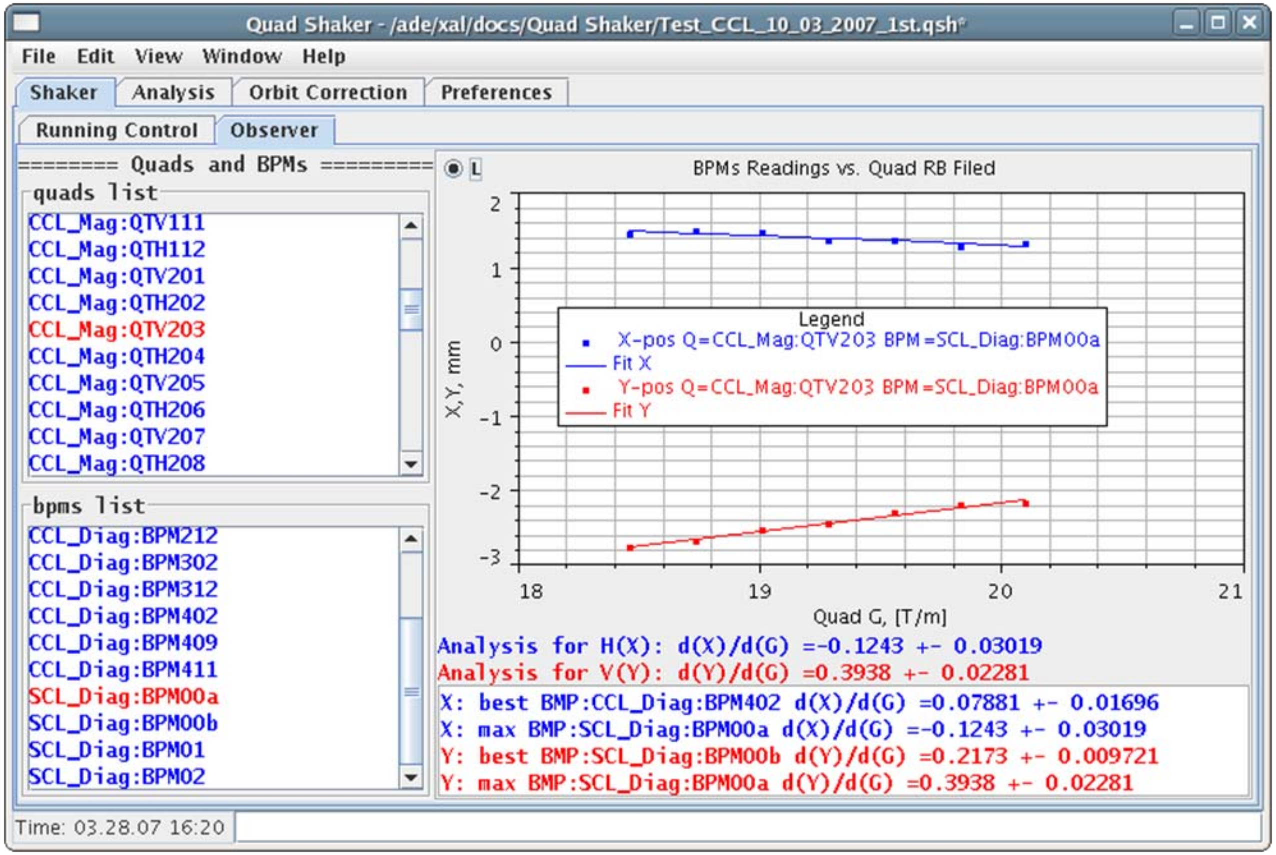
Beam Base Alignment

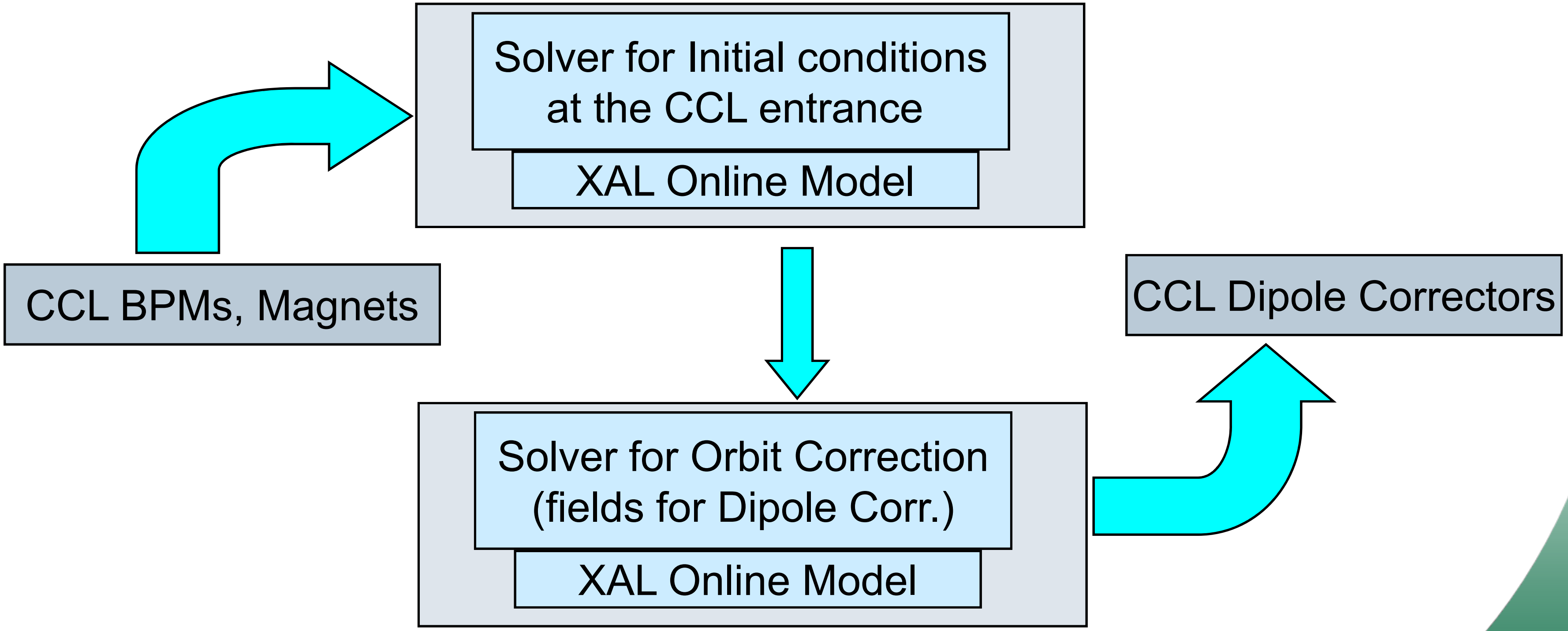
- **Quad Shaker XAL Application performs a beam based alignment**
- **Losses and activation dropped!**
- **It takes about 40 minutes (too long!)**
- **It needs the expert attention**



Model Based Orbit Correction

We can use the Online Model for orbit correction:

- **we can find the initial conditions (positions and angles of the beam) at the entrance of CCL by using BPMs readings and known live fields in quads and correctors**
- **Then we can find the orbit everywhere and find the correction to flatten it**

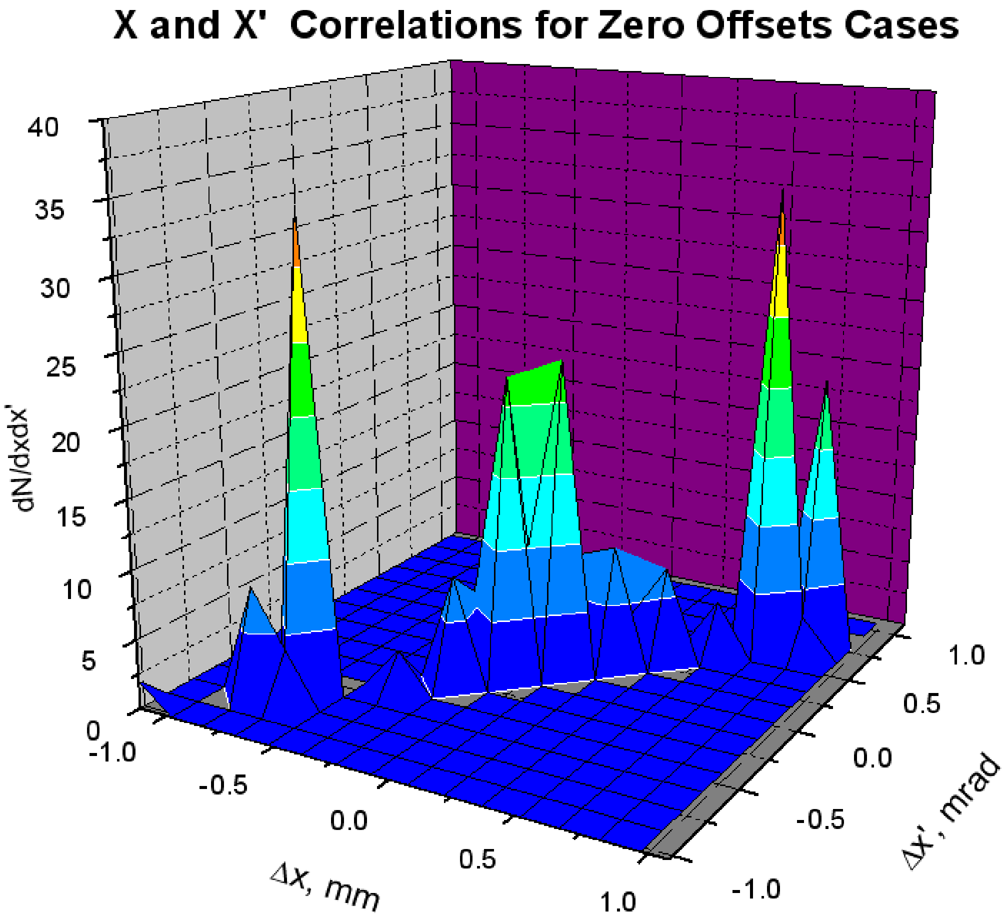


Problem is very simple! But it did not work!

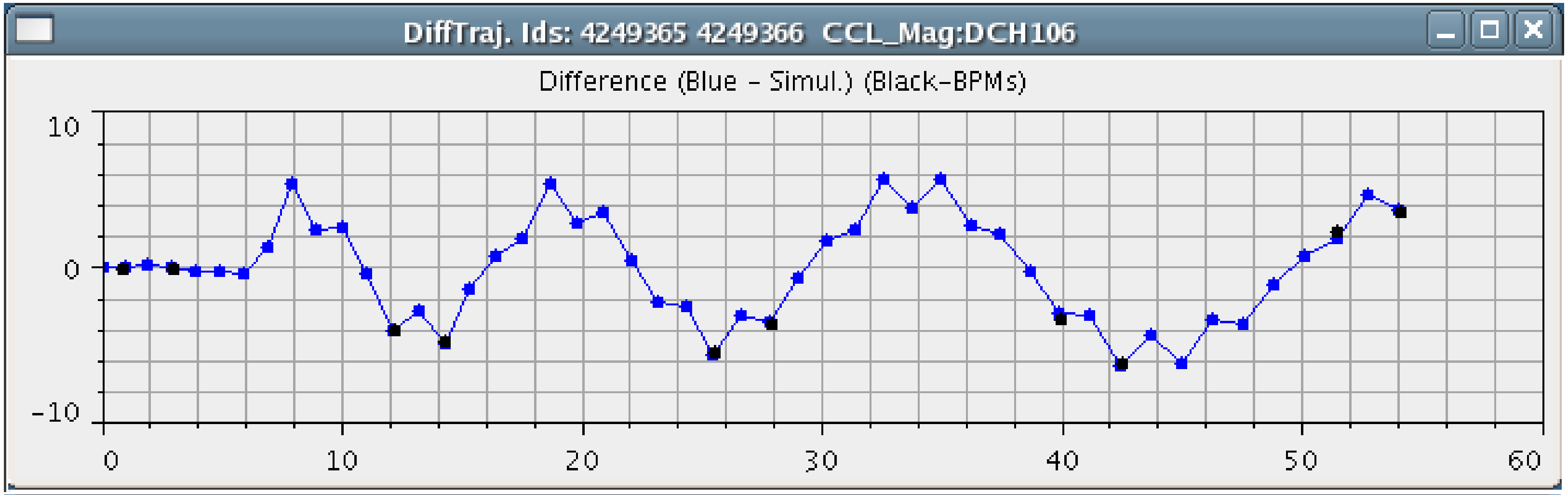
The First Stage – Initial Conditions

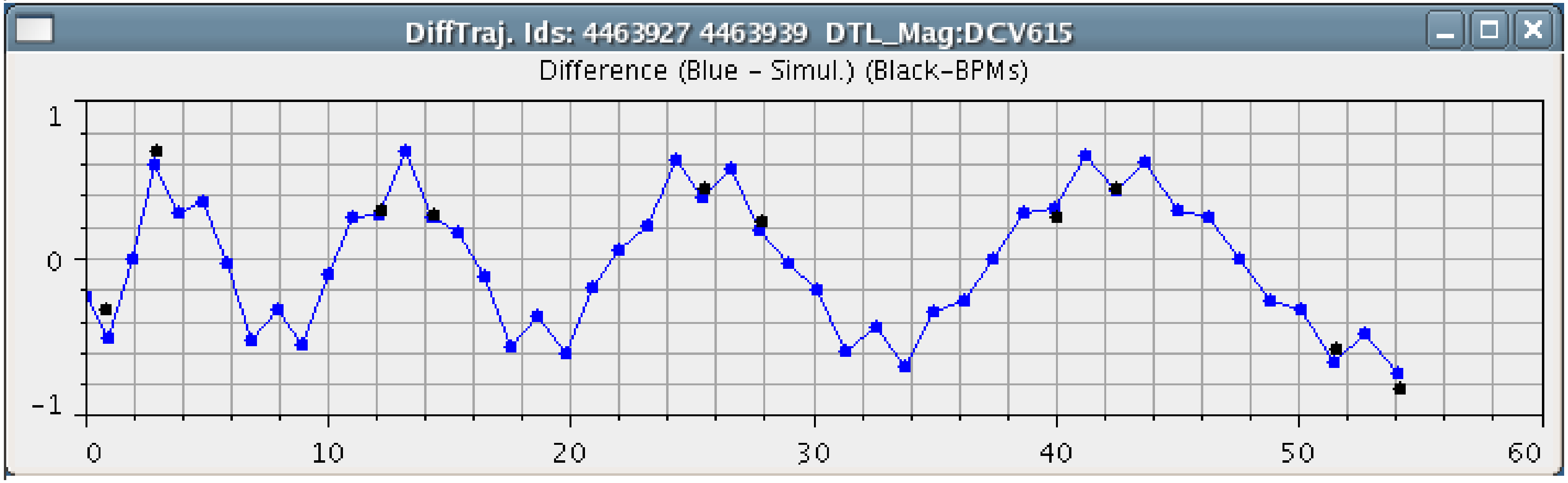
The large set of measured CCL orbits was analyzed. They were divided by cases in which initial conditions were the same.

The spread of "guessed" initial conditions was too big.



Orbit Difference – Model and Measurements Agree



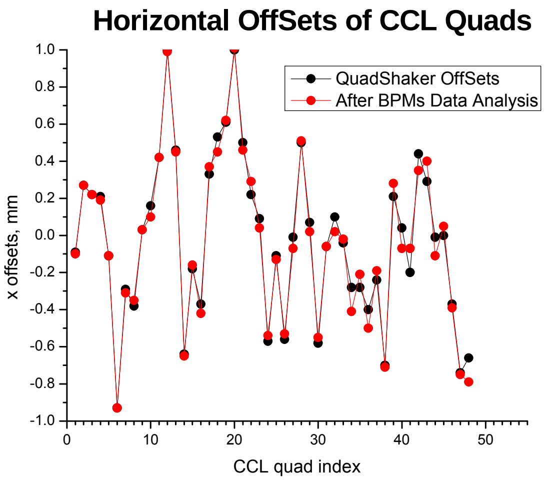


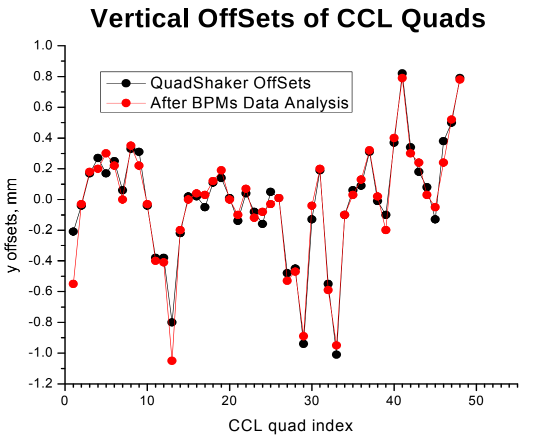
Model Based Orbit Correction (Cont.)

Result of studies:

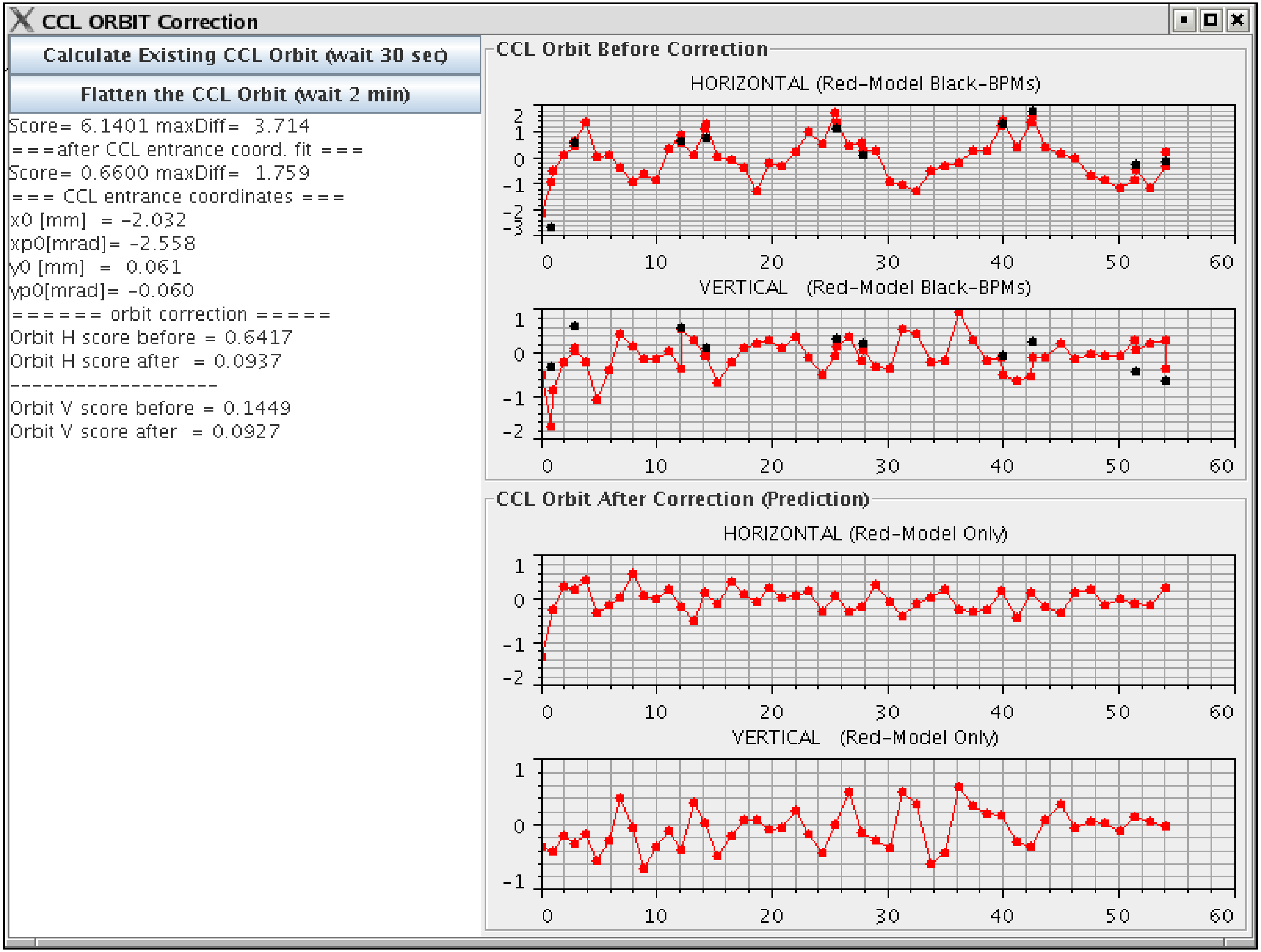
- **The model needs correction. Each quad and BPM has a non-zero transverse offset.**
- **The parameters were found after the analysis of about 3000 measured trajectories**
- **Modified model can predicts the BPM's signals with accuracy about 0.1 mm**
- **It takes about 30 seconds to flatten the CCL orbit, can be done parasitically, no expert is needed. One knob application.**

Found offsets are too big to be true. They should be considered integrated phenomenological corrections parameters





XAL Model Based Orbit Correction Application



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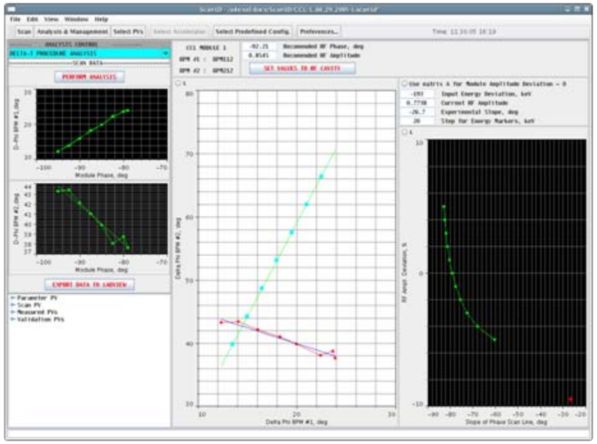
Longitudinal Tuning in Warm Linac



In the beginning we used the "Delta-T" method
- **Have to find an approximate values for amplitude and phase first**
- **Uses tables calculated offline**
- **Fast**

Later we switched to PASTA XAL Application: Phase/Amplitude Scan and Tuning Application

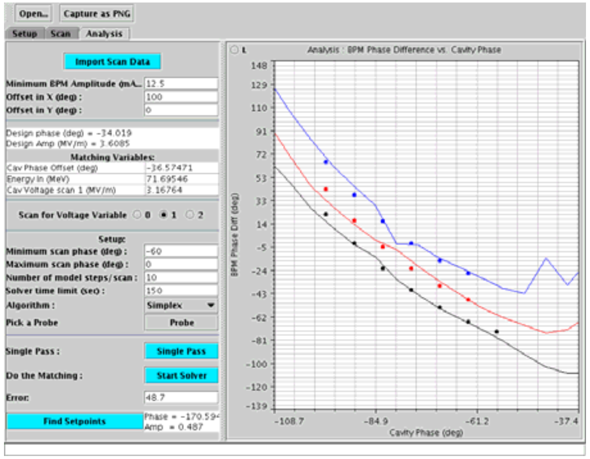
XAL Online Model - each RF gap is considered as a thin lens:

$$\Delta W(W_i,\Phi_i) = q\cdot V_0\cdot T(k)\cdot\cos(\Phi_i)$$

$$\Delta\Phi(W_i,\Phi_i) = \frac{q\cdot V_0}{\beta_i^2\cdot\gamma_i^3\cdot m}\cdot k\frac{\partial}{\partial k}\left[T(k)\right]\cdot\sin(\Phi_i)$$

$$k=\frac{2\pi}{\beta\cdot\lambda};\lambda = c\cdot\frac{1}{f}$$

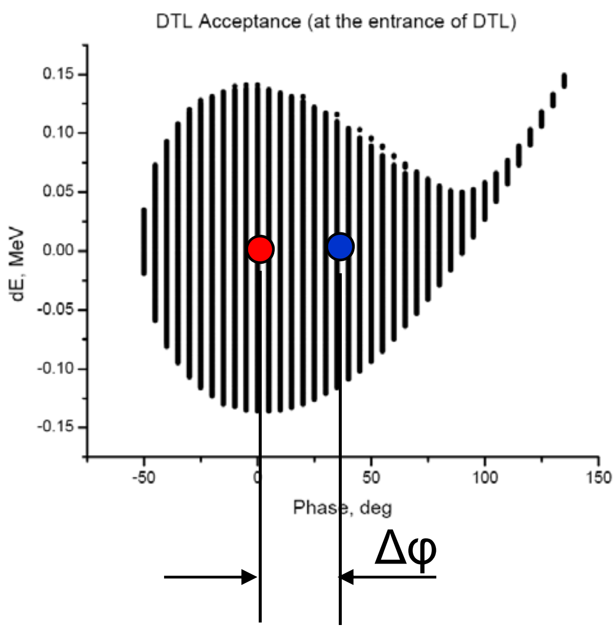
$$\frac{\partial(W_f,\Phi_f)}{\partial(W_i,\Phi_i)} = 1 + terms\ of\ order\left(\frac{q\cdot V}{W}\right)^2$$

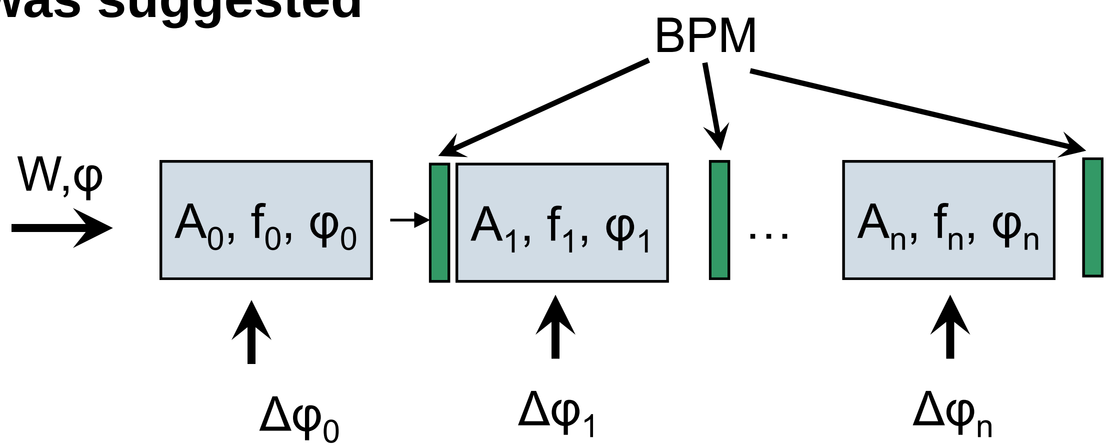


PASTA – XAL Application phase signature matching

Warm Linac – Longitudinal Tuning Correction

- **Due to different reasons, from time to time we need to correct cavity phases and amplitude or to check that the tuning is right**
- **The "Delta-T" or "phase signature matching" methods are too slow and can not be used "parasitically" during a production run**
- **The "longitudinal shaking" method with a small "phase shaking" amplitude was suggested**

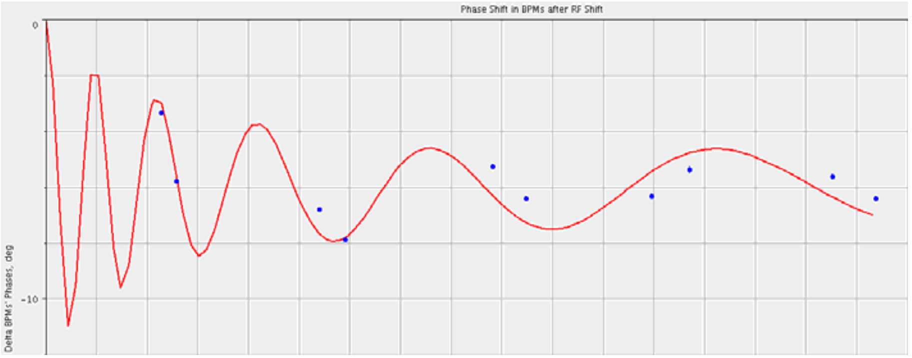


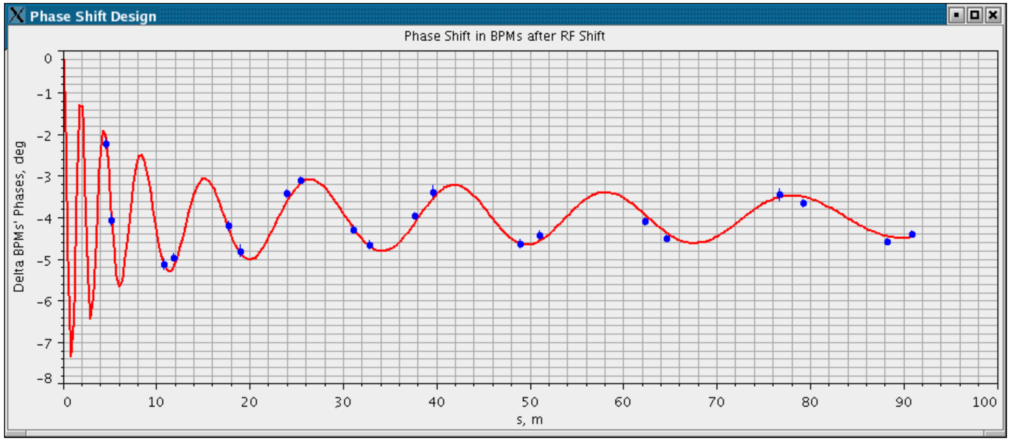


$$\Delta\varphi_i = (f_i/f_0)\Delta\varphi_0$$

Change in phases of all cavities is an equivalent to the change of the phase of the center of the bunch

Longitudinal Shaking





Comparison between measurements and design case calculated with the online model

Blue – BPM

Red – model for design case

$\Delta\varphi_{BPM}(s)$, s – BPM position

Advantages:

- **Technique can be used during production run. It does not effect losses, trajectory etc. downstream**
- **Interpretation very simple**

Drawbacks:

•It is difficult to correct several cavities at once. It has to be applied sequentially

•Used to correct amplitudes of cavities not phases

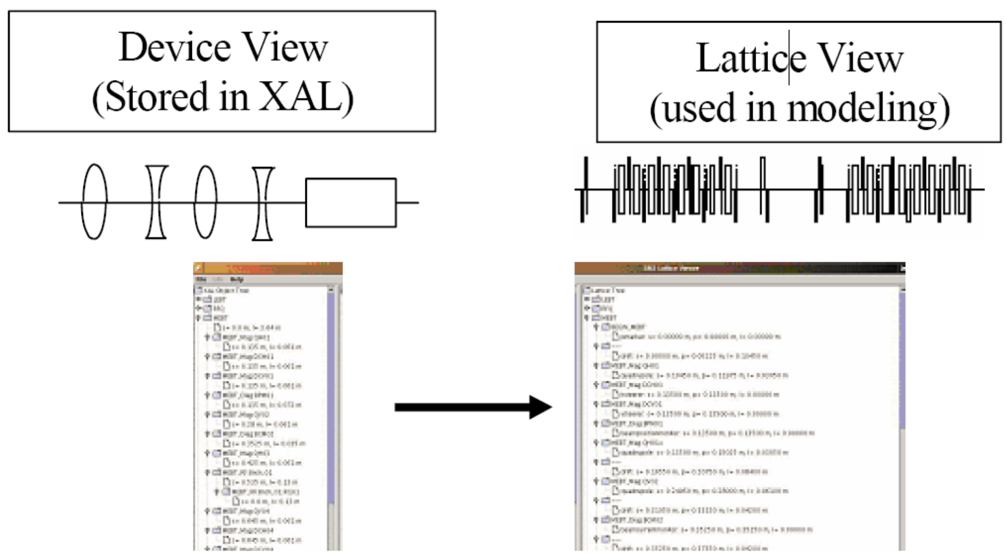
Conclusions

- **The single-particle models have their own niche**
  - **Simple and fast single particle online model can be a very valuable tool for linac tuning**
  - **Validated model can reduce the number of diagnostics stations**
  - **Some of diagnostics tasks can be done "parasitically" during the production runs**
- **We are looking ahead for more possibilities to use simple, fast, and available in a control room models**

Backup Slides

XAL Online Model

- **Calculate beam parameters.**
- **A lattice view of the machine is constructed from the “device”structure (via a set of rules.**
  - **Drifts are added, elements are split.**
  - **Device view -> intermediate lattice -> online model lattice**
- **Lattice element values can be updated from the machine, design, or logged values.**
- **Can do ‘what-if’ with any one of the above data sources.**
- **Mostly use an envelope model for single-pass linac tracking or closed orbit for ring.**



- Single entry per element *- Elements may be split*

- Only physical devices *-Includes drifts*