Pulsed-Focusing Recirculating Linacs for Muon Acceleration: Introduction and Status

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Alex Bogacz, Yves Roblin, Jefferson Lab

Vasiliy Morozov, Old Dominion University & Muons,Inc.

Muons, Inc.

Jefferson Lab

Old Dominion University

MAP meeting 7 May 2010

Overview

SBIR-II grant

SBIR Project DE-FG02-08ER86351

Pulsed-Focusing Recirculating Linacs for Muon Acceleration

- **Aug 2009 – Aug 2011**
- **First funding April 16, 2010**
- **Midterm report due May 15, 2010**

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(paraphrased) SBIR Goals

1. Determine realistic pulsed quadrupole parameters to be combined with ILC accelerating structures.

2. Implement the FODO lattice for a 1.3 GHz ILC-type SRF accelerating structure to determine the maximum number of passes achievable

3. Design the corresponding droplet arc using a FODO lattice.

4. Chromatic effects will be assessed and compensations schemes designed

5. Prepare a plan for the design of a full accelerator complex using multi-pass RLAs in order to achieve TeV energies.

6. Simulate the energy deposition due to muon decay and mitigation methods.

Approximate Manpower/year

Muons Inc. ..... 1 FTE

K.Beard, R.Johnson

Jefferson Lab ..... 0.5 FTE

A.Bogacz, V.Morozov, Y.Roblin

Collaborating with

Imperial College, London, UK ....

M.Aslaninejad, C.Bontoiu, J.Pozimski

Brookhaven Lab.....

D. Trbojevic

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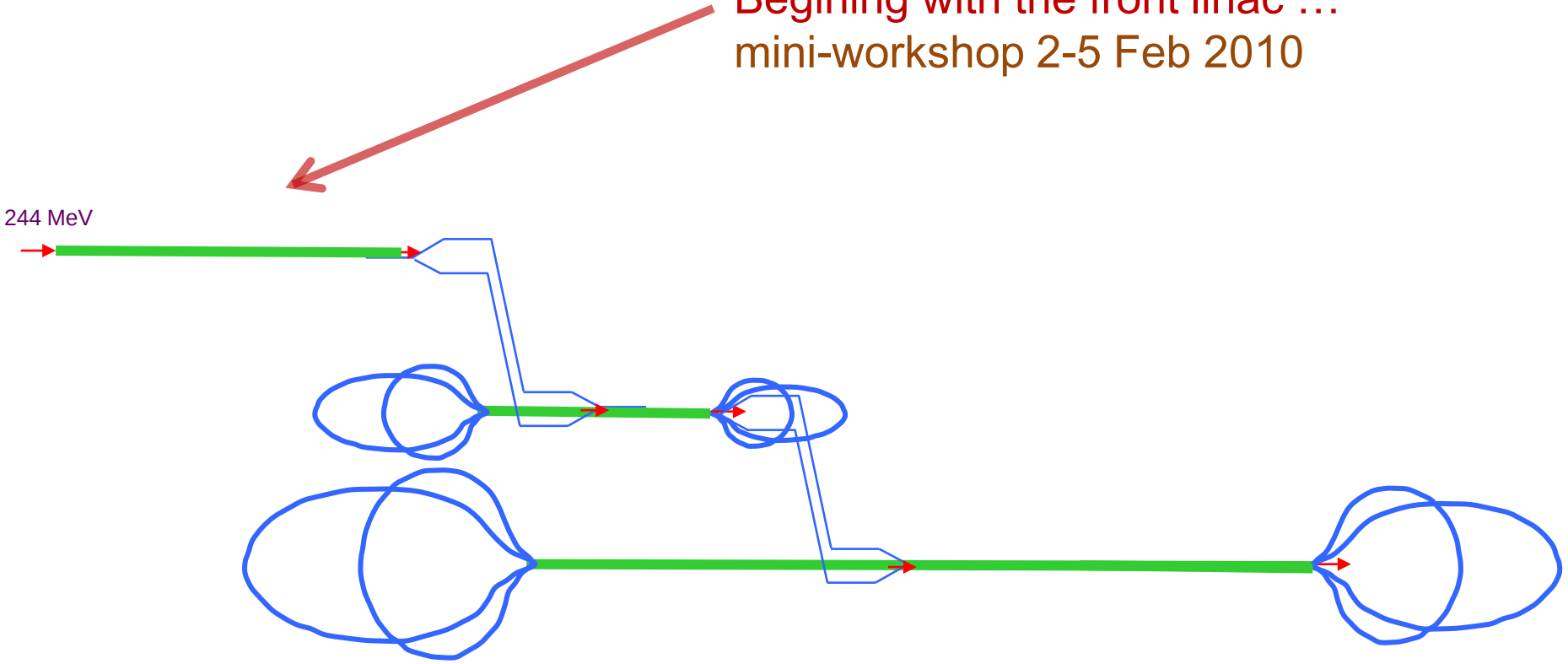
Jefferson Lab

Old Dominion University

Imperial College London

Status – view from afar

Begining with the front linac …
mini-workshop 2-5 Feb 2010



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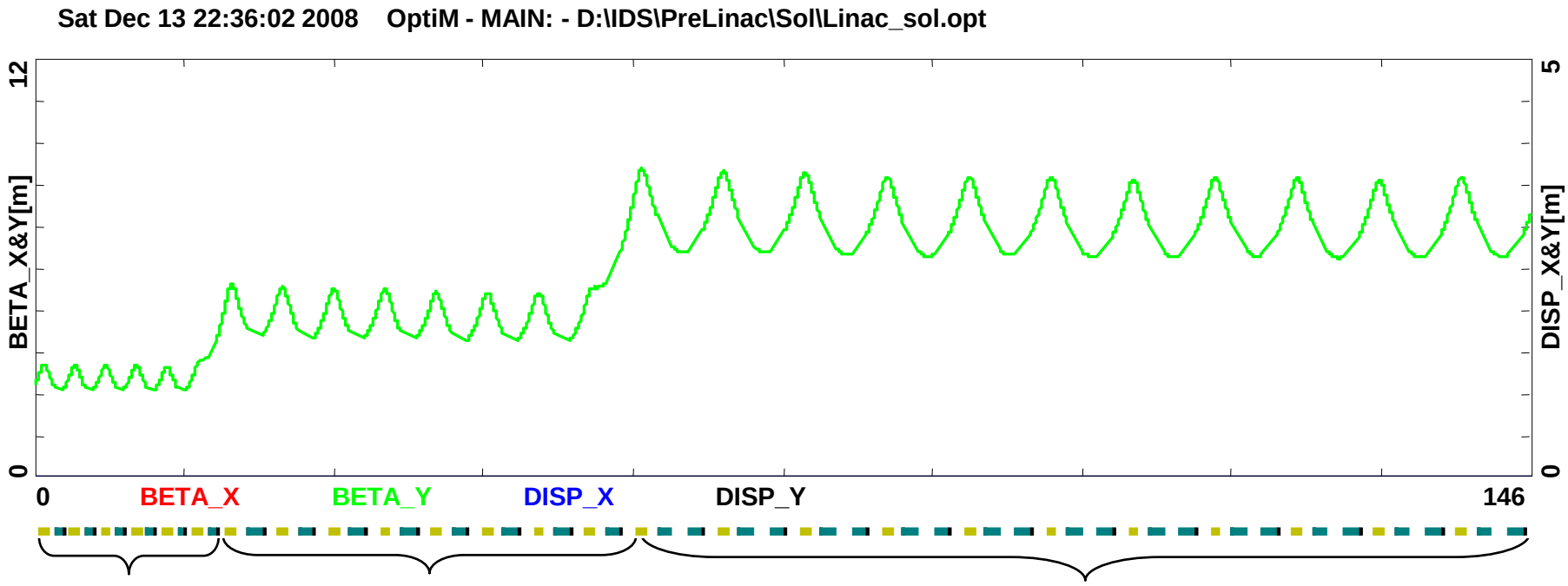
Solenoid Linac (244 -909 MeV)



6 short cryos

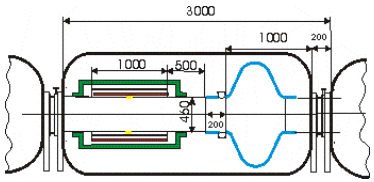
15 MV/m

8 medium cryos

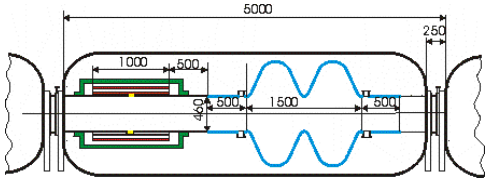
17 MV/m

11 long cryos

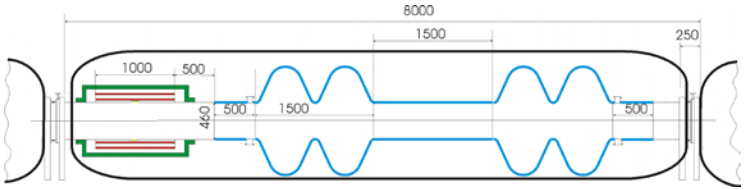
17 MV/m



1.1 Tesla solenoid

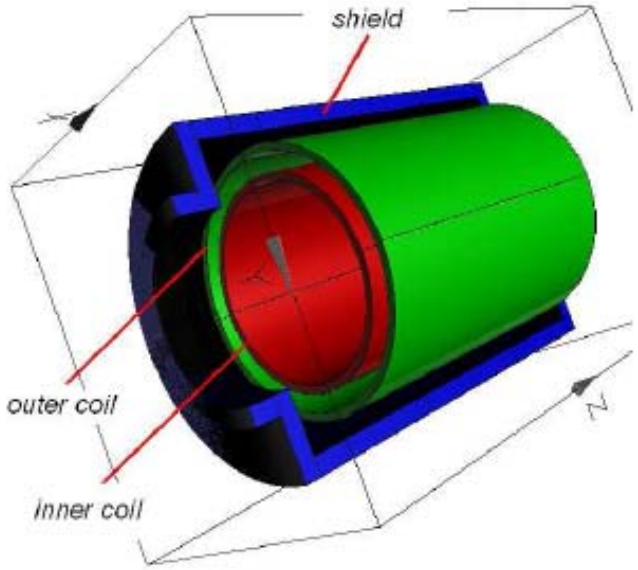


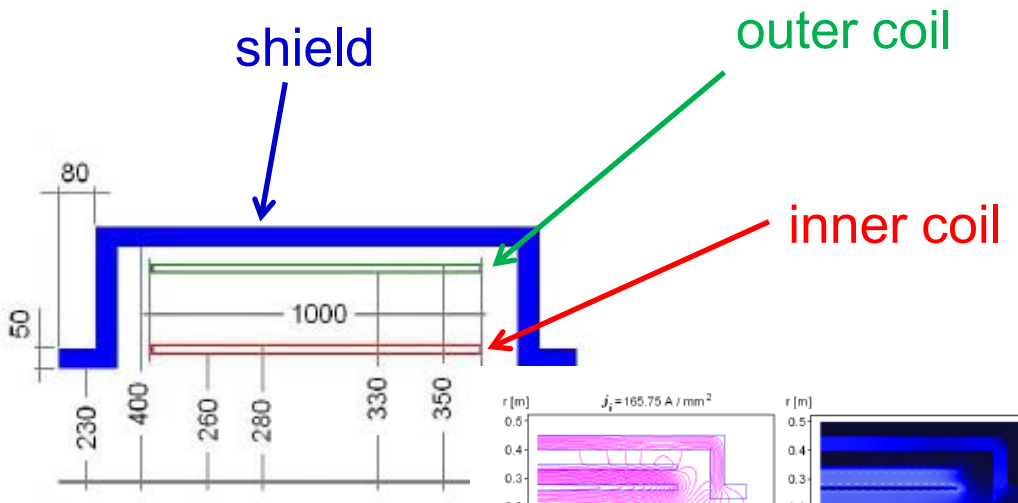
1.4 Tesla solenoid

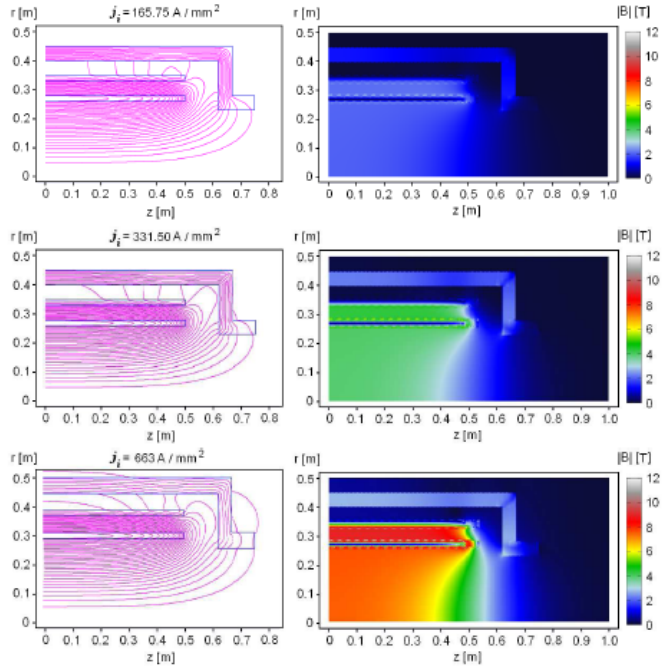


2.4 Tesla solenoid

Solenoid Model (Superfish)







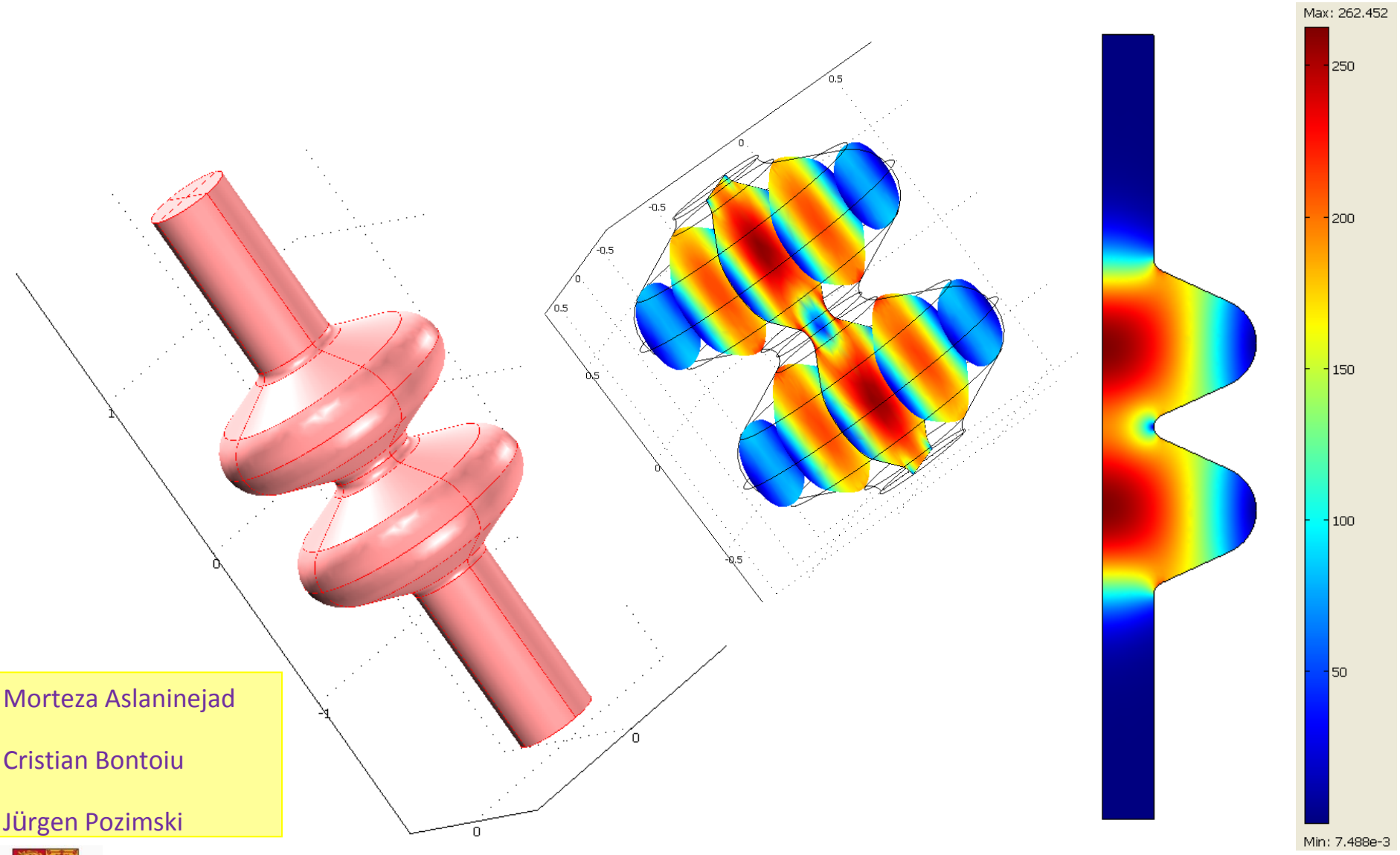
Morteza Aslaninejad
Cristian Bonţoiu
Jürgen Pozimski

'Soft-edge' Solenoid (s>0)

$$B_z(s) = \frac{1}{2} B_0 \left[1 - \tanh\left(\frac{s - L/2}{a} \right) \right]$$

$$\Phi_{edge} = \frac{1}{2}\left(\frac{e}{pc}\right)^2 \left(\int_{-\infty}^{\infty} B_z^2(s)\, ds - B_0^2 L \right) = -\frac{k^2 a}{8} \qquad k = \frac{e}{pc} B_0$$

Two-cell cavity (201 MHz) – COMSOL



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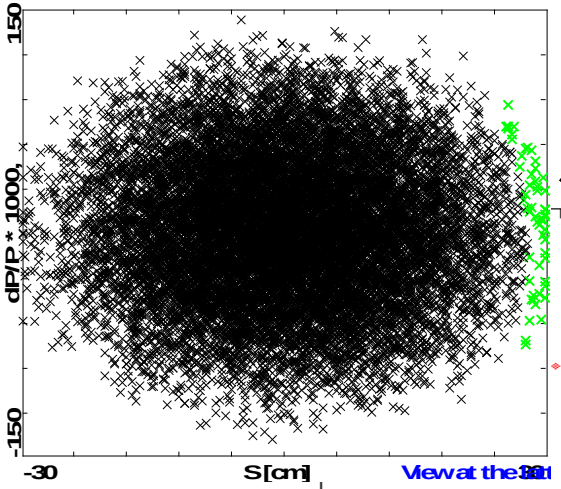
Cristian Bontoiu

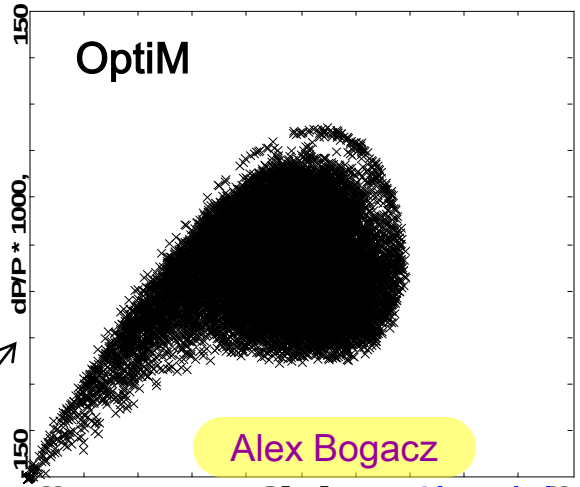
Jürgen Pozimski

Imperial College London

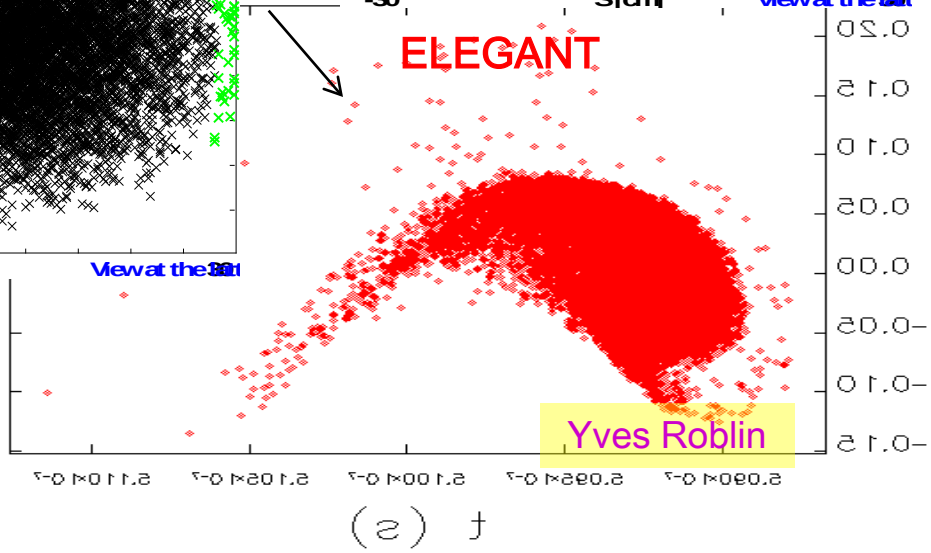
Longitudinal phase-space tracking

Initial distribution



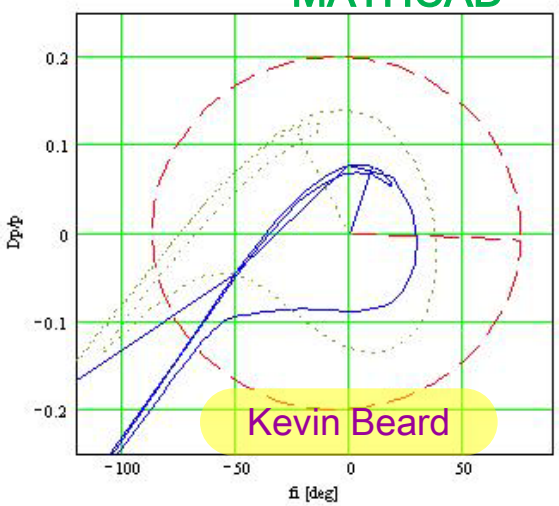


Alex Bogacz



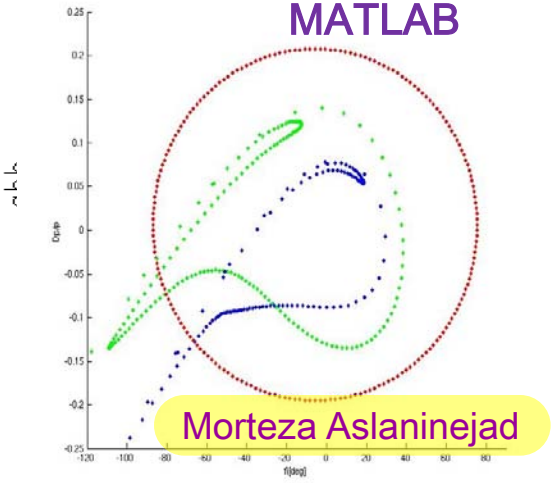
Yves Roblin

MATHCAD



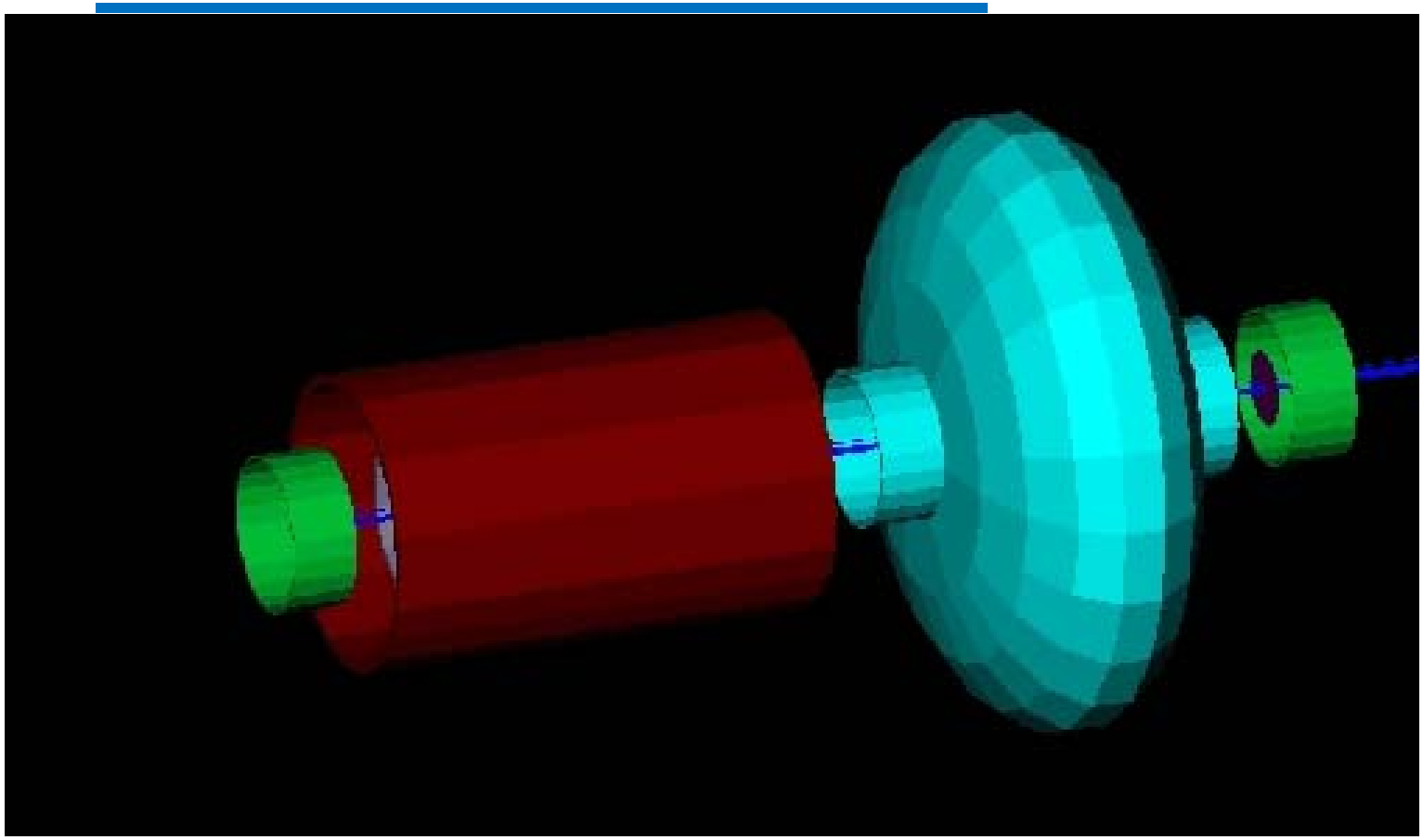
Kevin Beard

MATLAB



Morteza Aslaninejad

G4beamline 2.02



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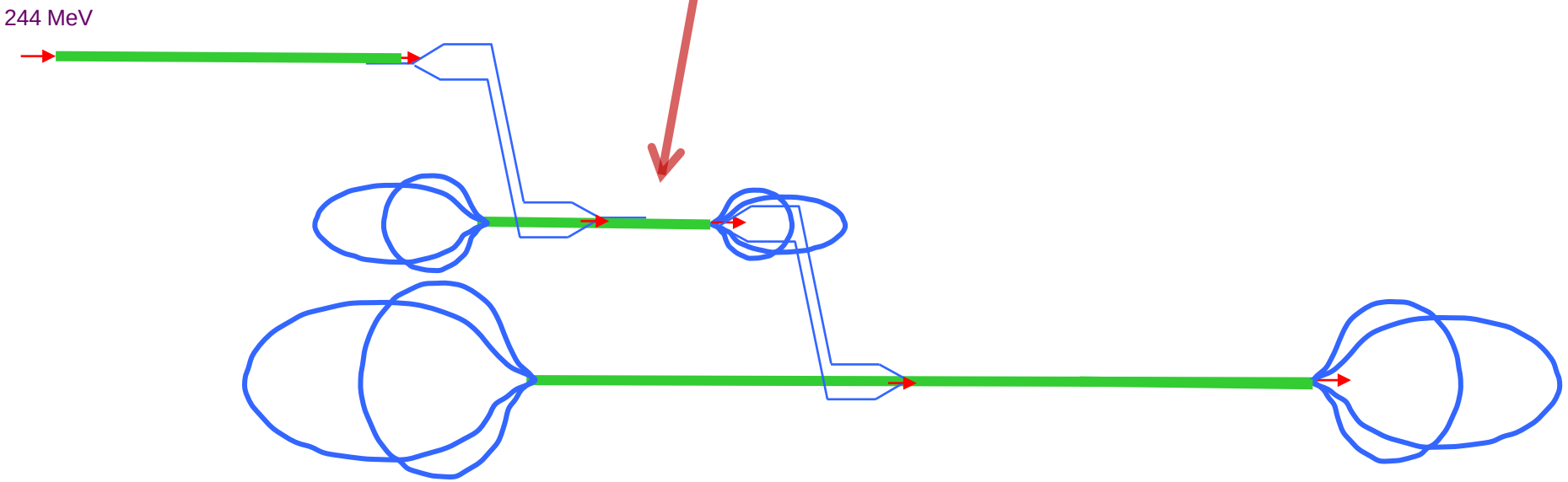
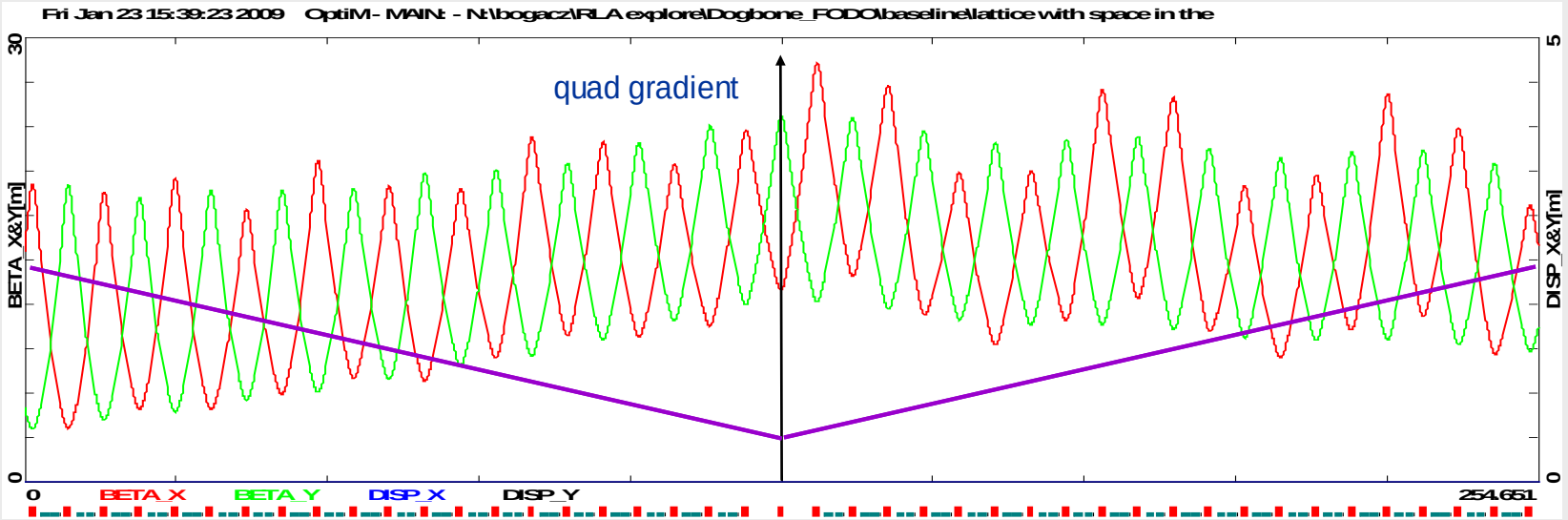
Status – moving along

Low energy (<~30 GeV) RLA …
Beta beating in linac + return arcs …

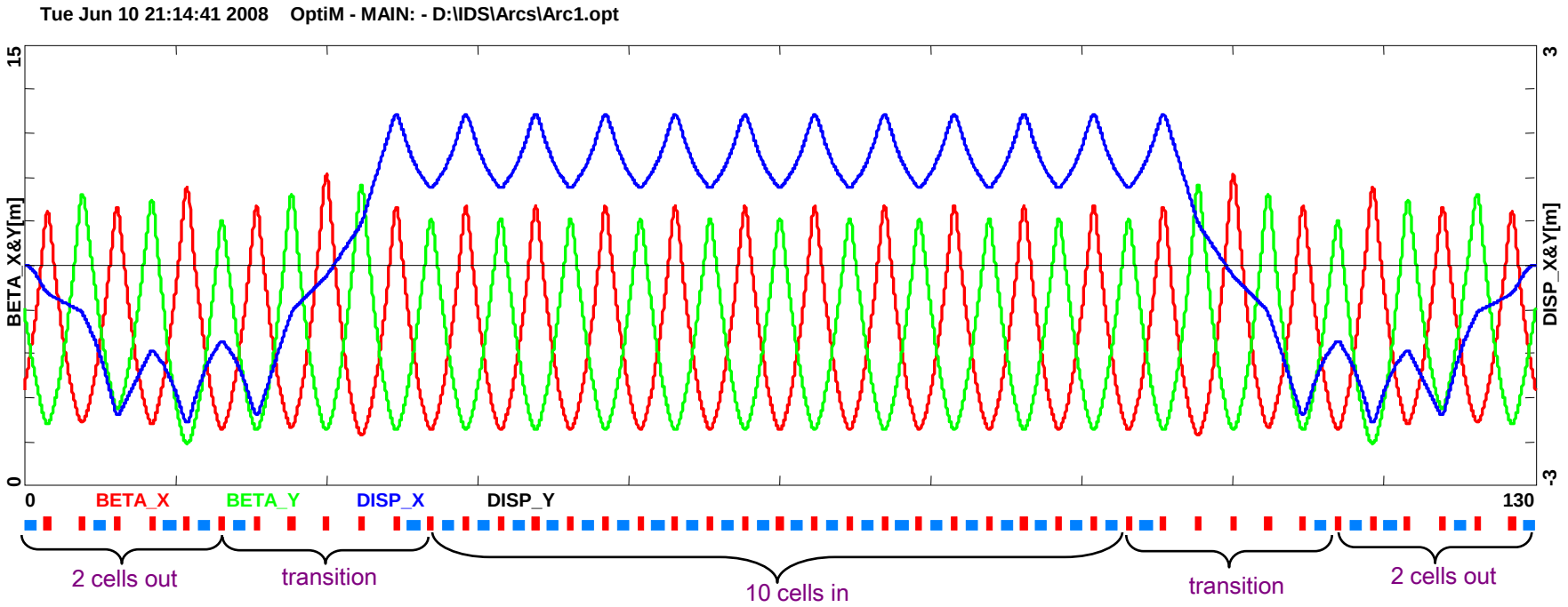


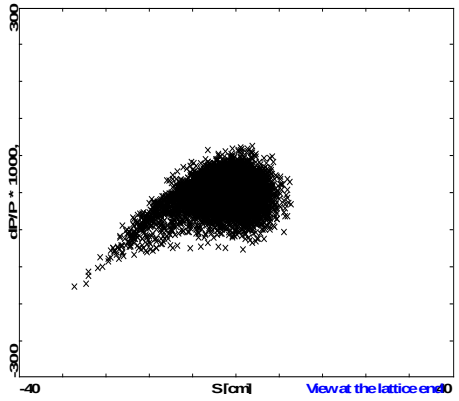
Bisected linac optics

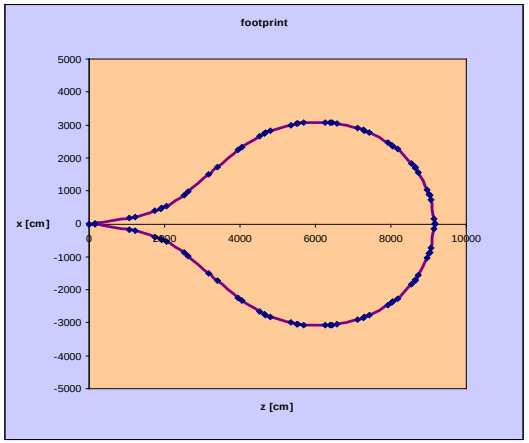
- mirror symmetric quadrupole gradient profile minimizing under-focus beta beating

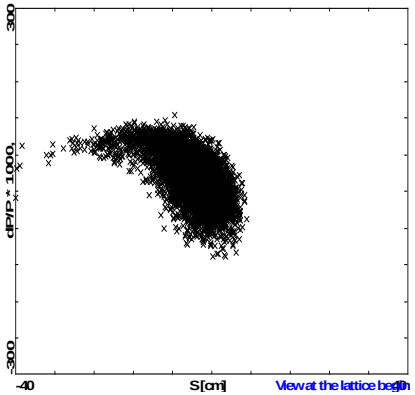


Mirror-symmetric 'Droplet' Arc – Optics



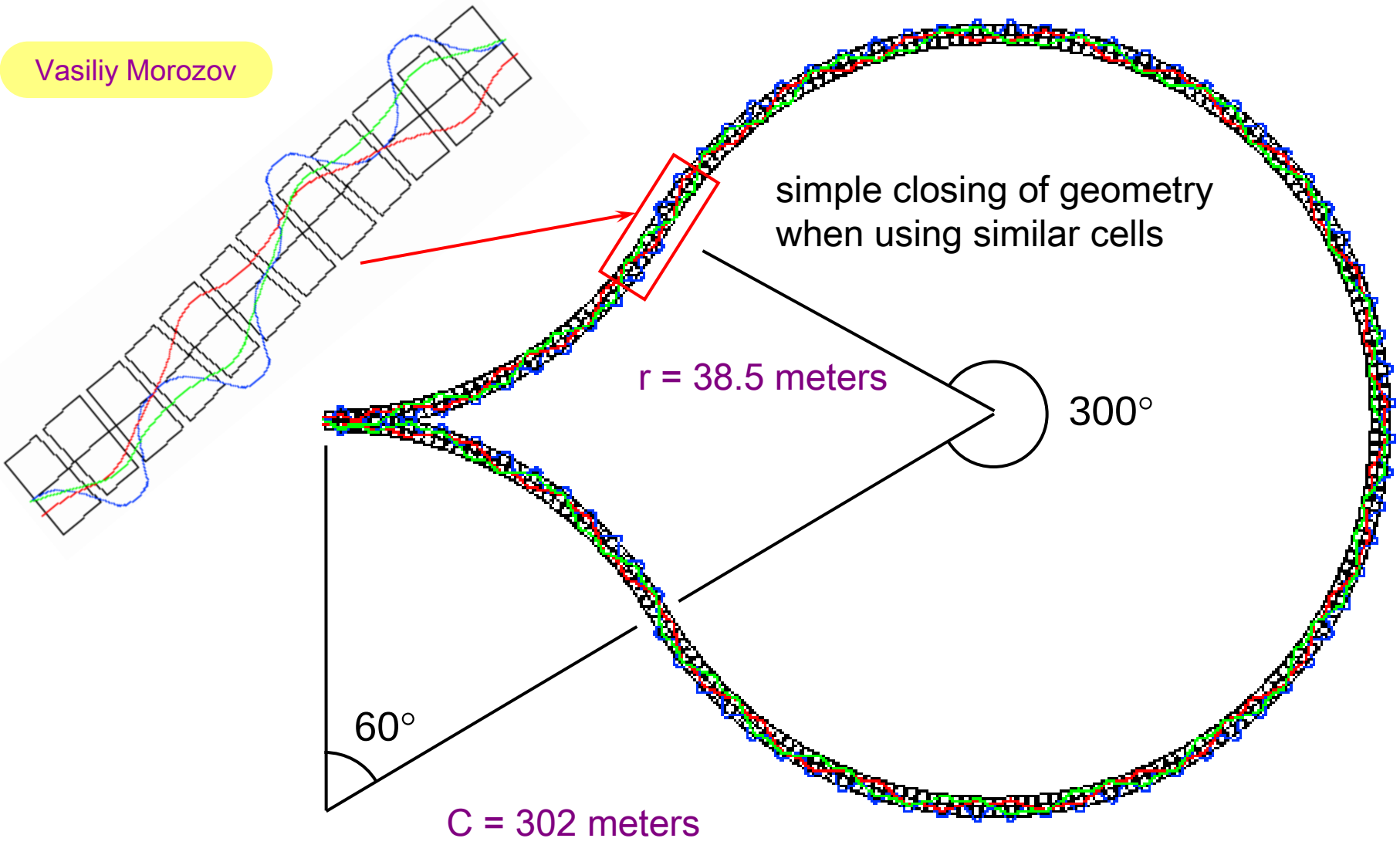


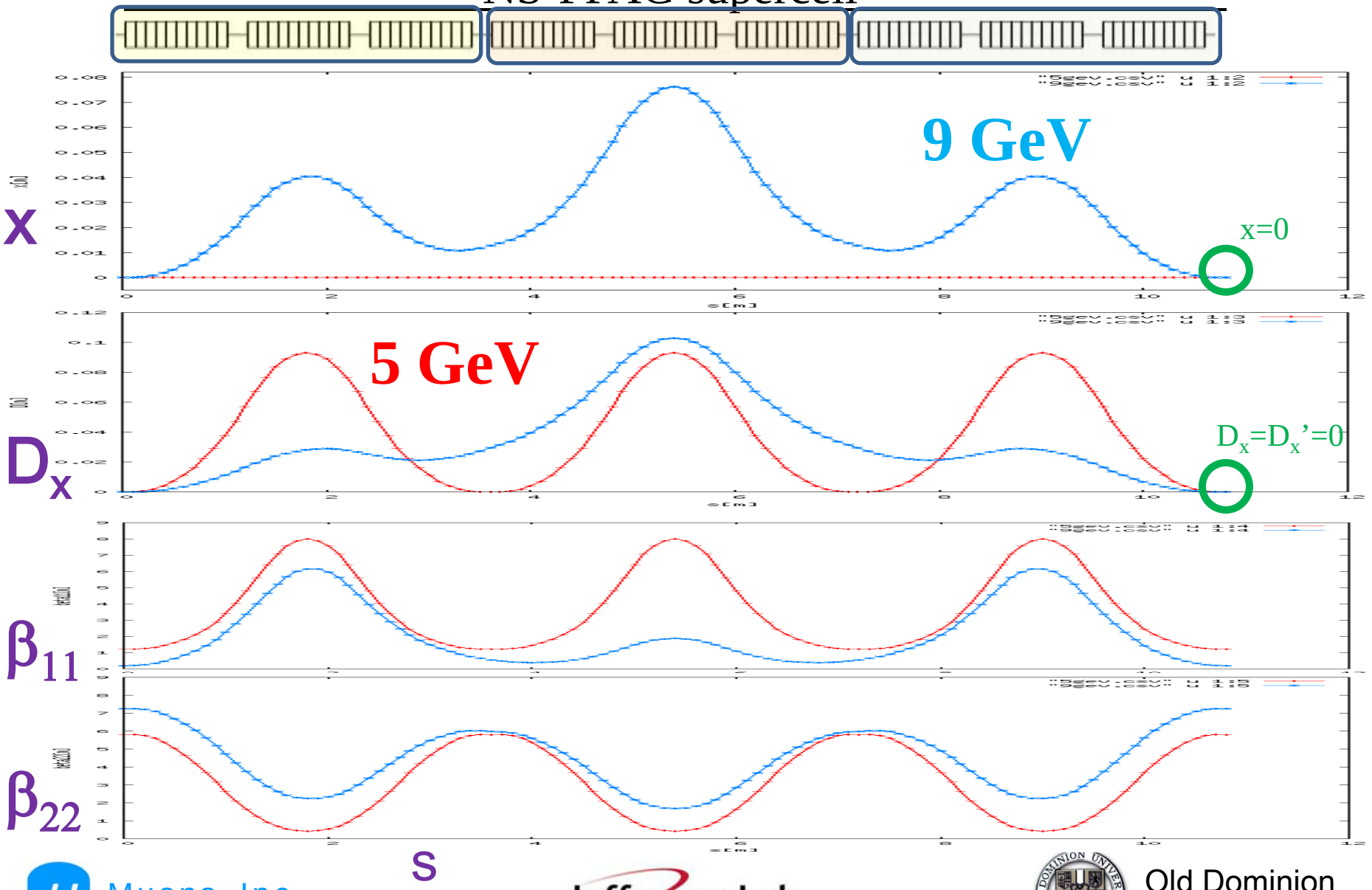




Multi-pass FFAG Arc

Vasiliy Morozov





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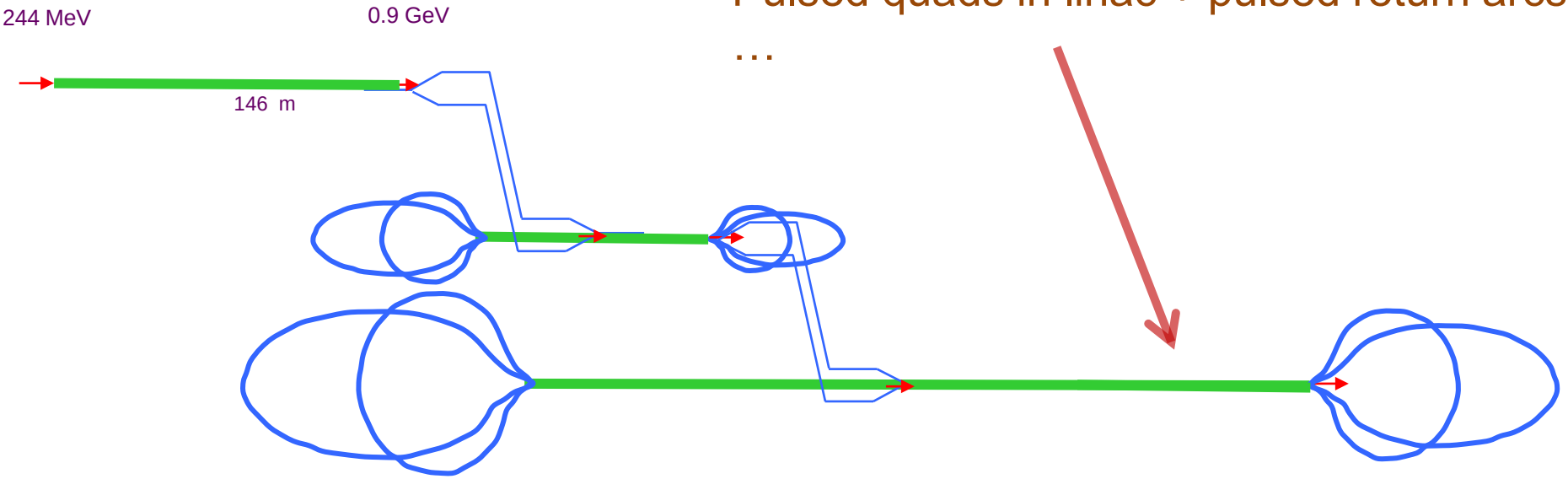
Status – moving along

High energy (>~30 GeV) RLA …
Pulsed quads in linac + pulsed return arcs
…

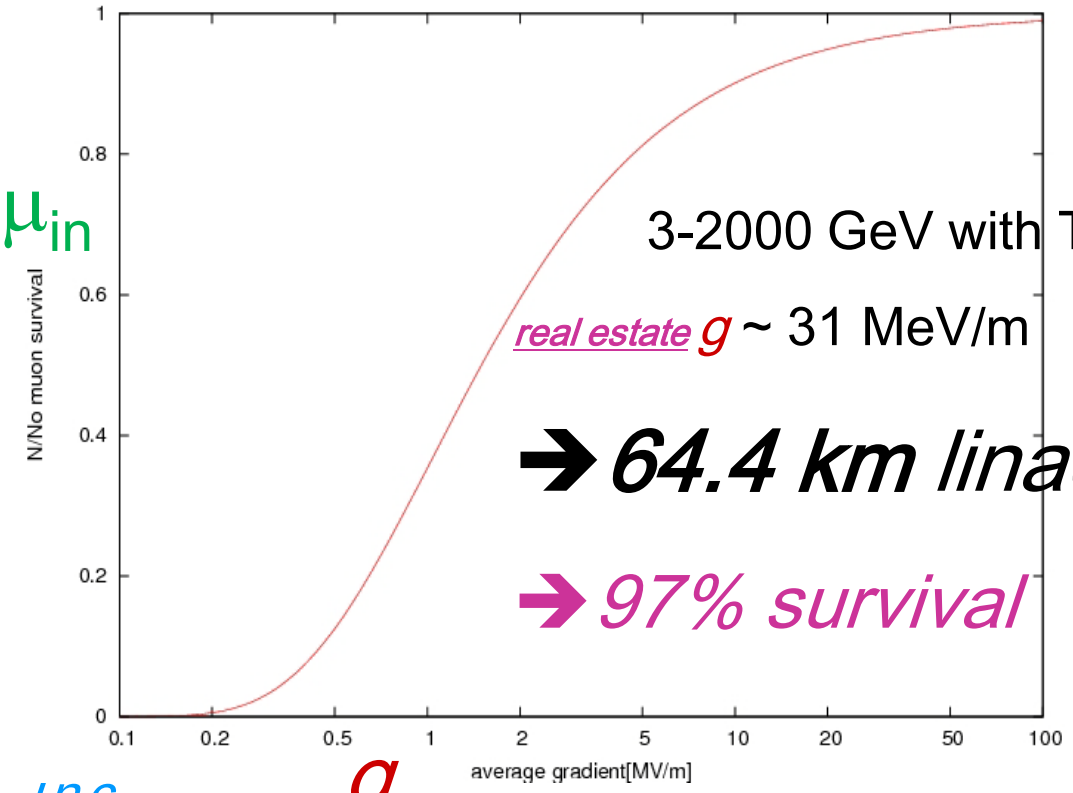


The very big picture….

(average gradient over whole path)

$$N/N_o = e^{-\lambda \Delta t_\mu} = (E_f/E_i)^{-\lambda m_o/gc}$$

$\#\mu_{out} / \#\mu_{in}$



3-2000 GeV with TELSA cavities

real estate g ~ 31 MeV/m

➔ ***64.4 km linac***

➔ *97% survival*

g

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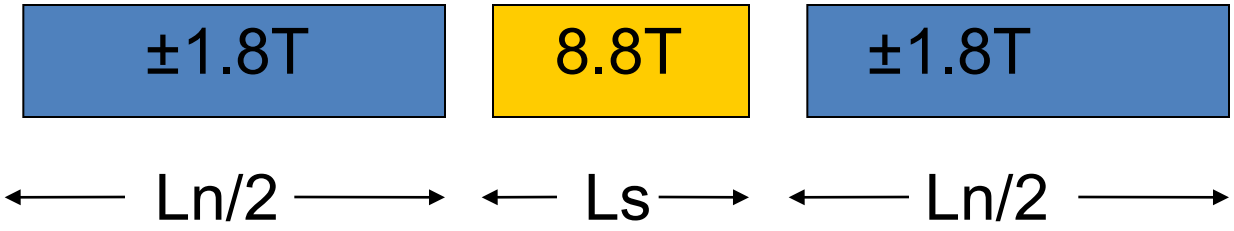
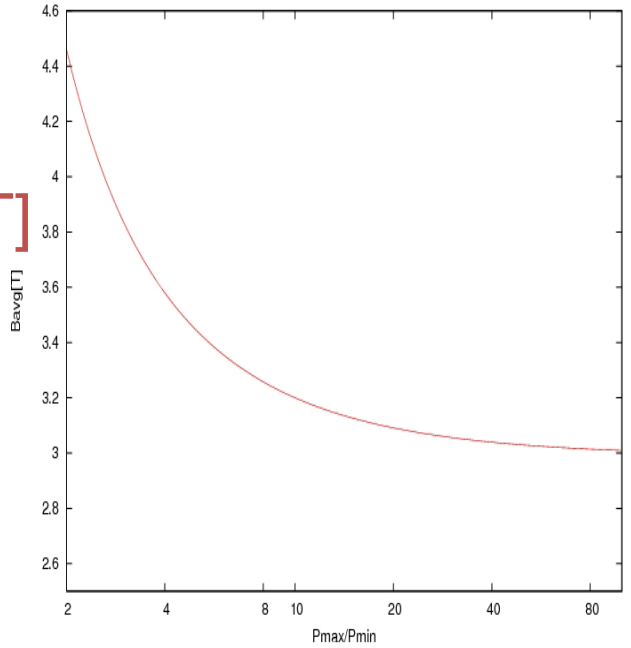
Hybrid magnets…



$x \equiv (P_{max}/P_{min}-1)/(P_{max}/P_{min}+1)$

$B_{avg} = f\,(x+1)/(x/Bn+1/Bs)$



B_{avg}[T]

P_{max}/P_{min}

$P_{max}/P_{min} \rightarrow \infty$, $B_{avg} \rightarrow$ **3.0T**

Even if you had infinitely strong superconducting magnets

$P_{max}/P_{min} \rightarrow \infty$, $Bs \rightarrow \infty$ $B_{avg} \rightarrow 2\,Bn$

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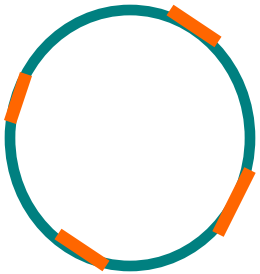
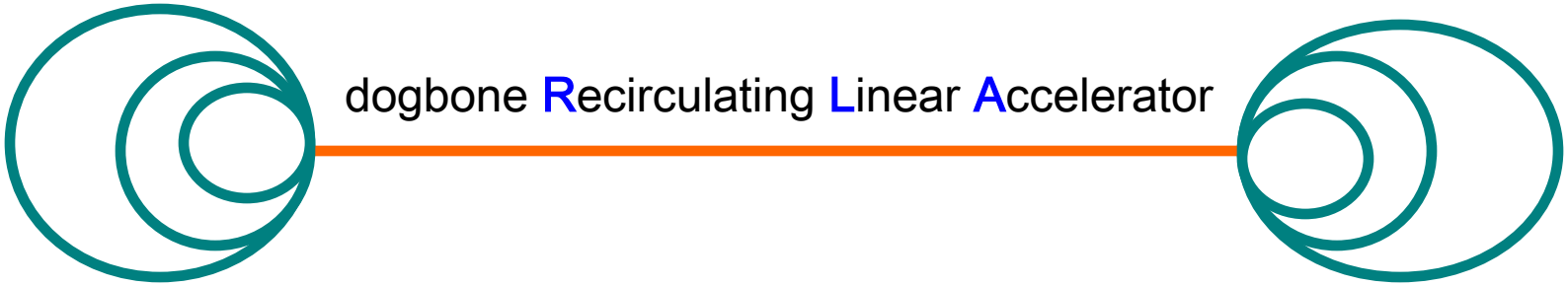
Reuse RF … lots of schemes…



Rapid Cycling Synchrotron

All of these require rapidly pulsed magnets and so begin to resemble each other.

racetrack recirculating linac



dogbone Recirculating Linear Accelerator

Recent Accomplishments

- mini-workshop held in Feb 2009 on the front linac
- Muon Acceleration Group has a website:

  http://casa.jlab.org/external/MuonAccelerationGroup/

- various simulations & optimization of linac in progress
- low energy RLA linac lattice simulated (~4.5 – 9 passes)
- RLA FFAG arcs studied to support large # of passes
- one good 5:9 FFAG arc solution now found & being studied
- RLA chromaticity compensation being simulated
- RLA linac-to-arc matching being considered

Near term goals

- finish midterm report and IPAC2010 papers
- optimize front linac in **`g4beamline 2.02`** using realistic fields
- radiation loads simulated
- low energy FFAG arcs for devised and tested with tracking
- low energy RLA linac, arcs & matching designed & simulated
- low energy RLA chromaticity compensation study
- Putting the pieces together for end-to-end simulations
- prepare for IDS-NF report in Sep 2010

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Long term goals

- select basic arc magnet design for high energy RLA
- select basic pulsed quadrupole magnet design for high energy RLA
- estimate radiation loads and effects
- estimate costs and use to optimize high energy RLA layout
- create & optimize lattice for optimized RLA layout
- simulate front linac and RLAs end-to-end
- write final SBIR report in 2011