LEDA RFQ

Design to accept beam from a weak focusing LEBT

Lloyd Young

Several new improvements :

- Coupled segments 4 x 2m long RFQs
  - ⇒ 8m long RFQ ⇒ high energy (6.7
  - ⇒ Electromagnetic quadrupoles in the DTL
  - ⇒ relaxed mechanical tolerences ⇒ lower c

- Optimized beam dynamics

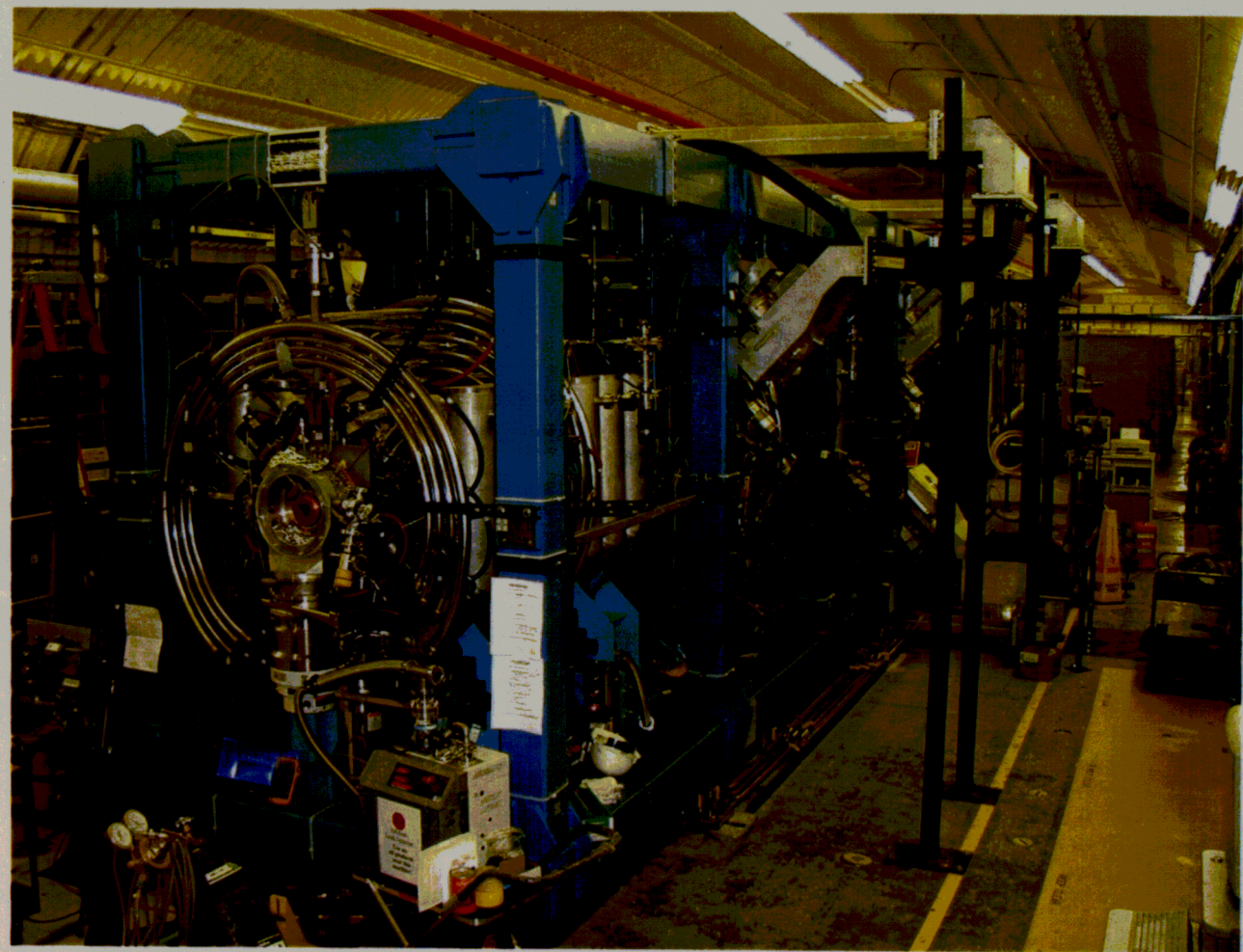
  Vane voltage and radius "r_0" adjusted ($f(z)$) in each RFQ section (input - bunching - acceleratio

⇓

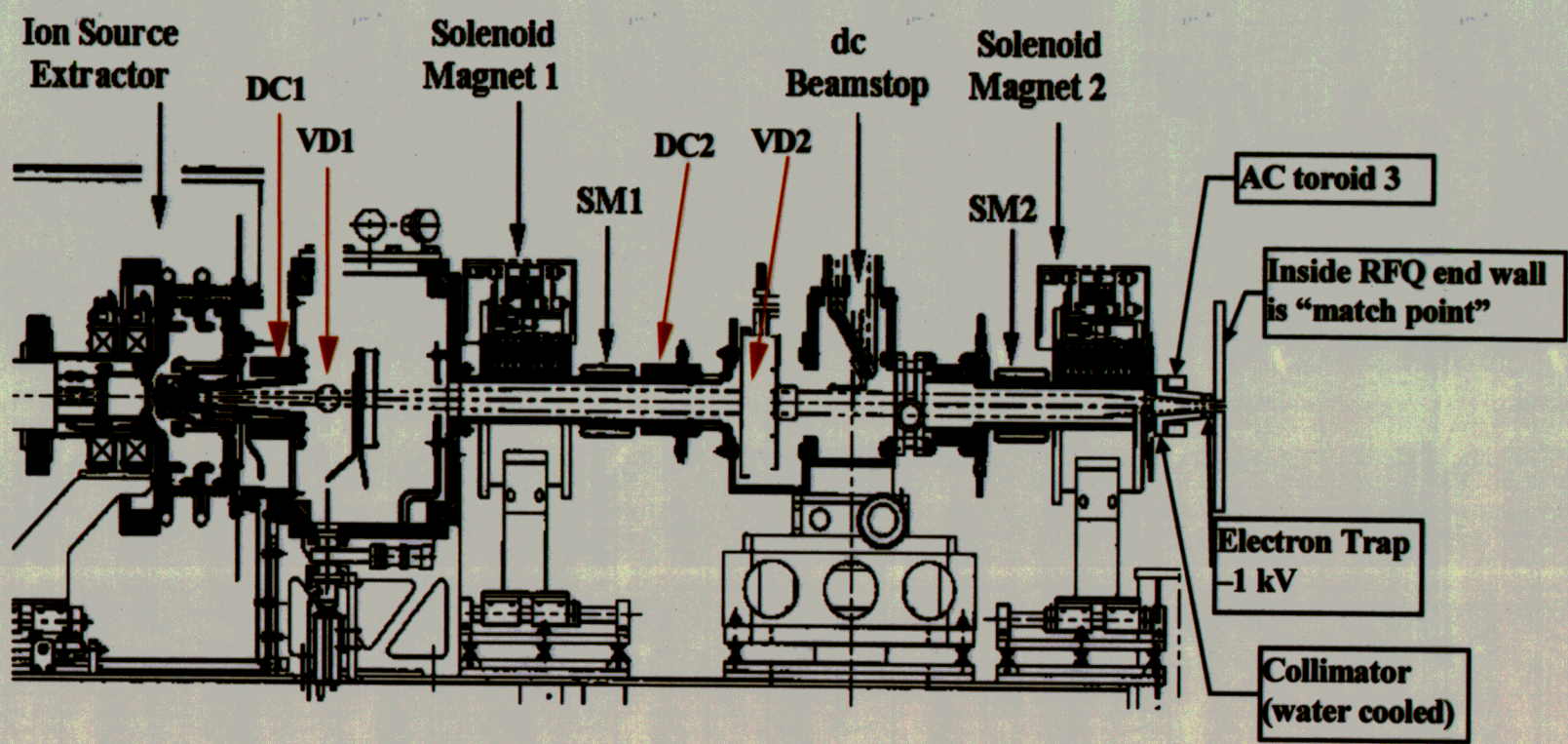
6.7 MeV 100 mA CW ⇒ 0.67 M

relaxed constraints on the LEBT and following section

RFQ with 6 waveguide RF feeds.

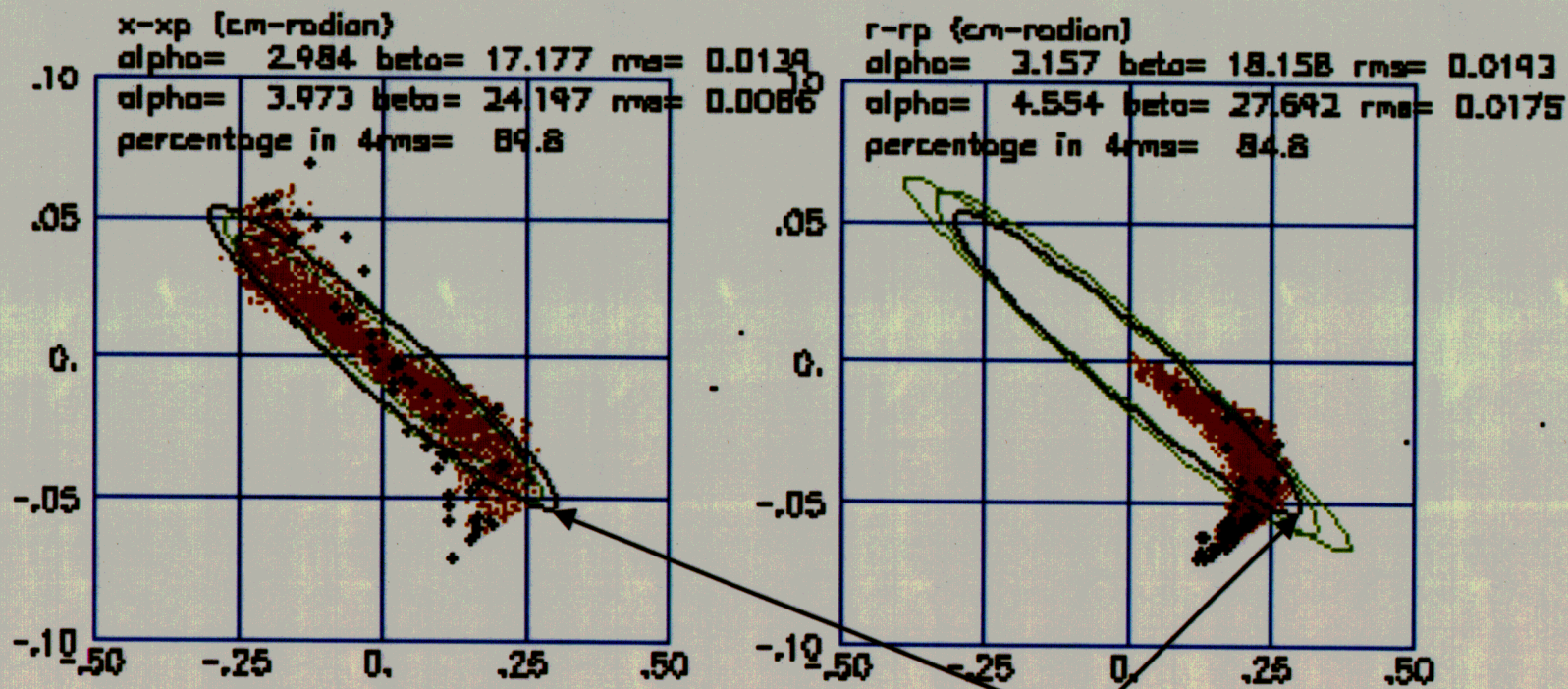


Low Energy Beam Transport (LEBT)



LEBT beam line with electron trap.

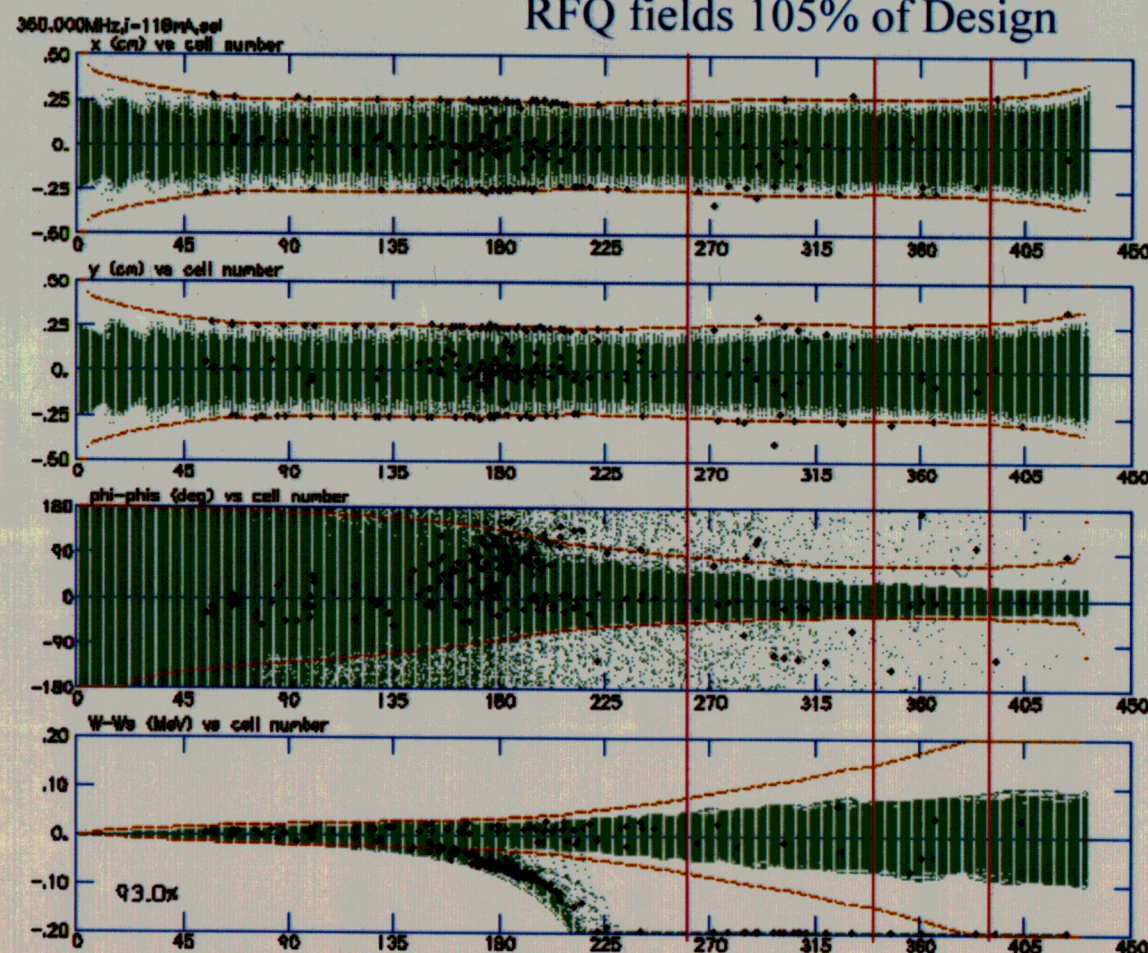
Phase-space at input to RFQ with solenoid 15 cm spacing and "e-trap"



Ideal shape of phase space ellipse to match beam into RFQ (.01 π mm-mrad.)

RFQ simulations show 93% transmission through RFQ using input distribution from PARMELA simulation of LEBT (15 cm solenoid spacing and "e-trap".)(108.5 mA in; 101mA out.)

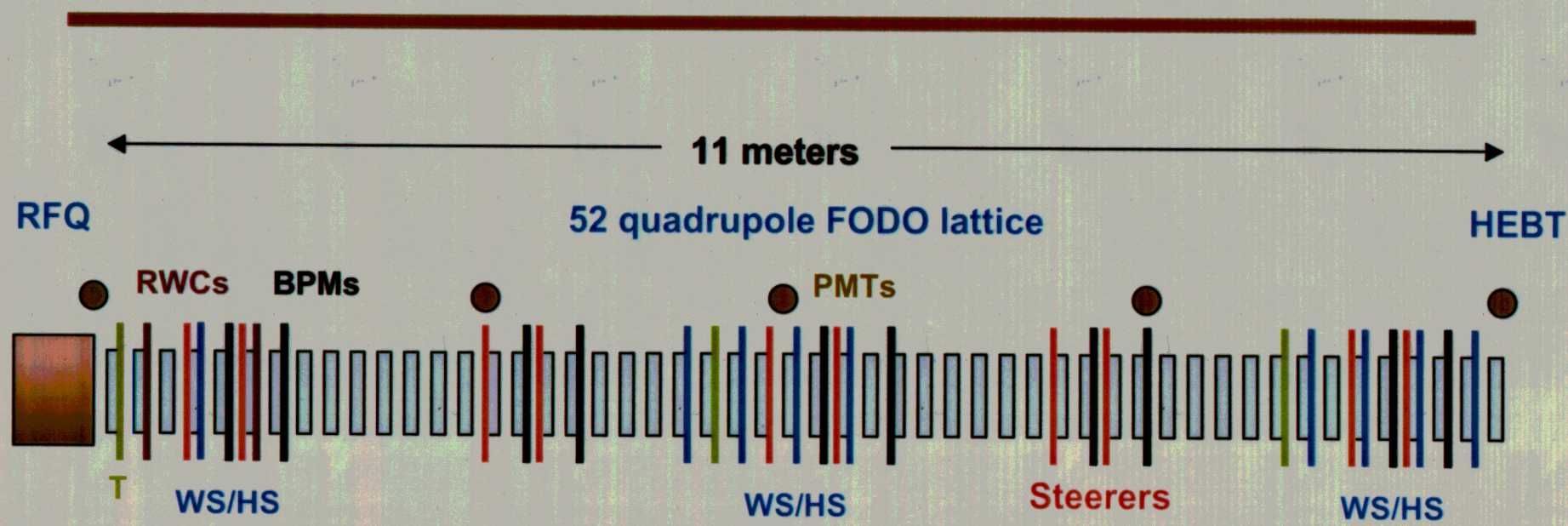
RFQ fields 105% of Design



PARMTEQM simulation includes the effect of multipoles. The RFQ design has a radial matching section, a shaper section, a gentle buncher, an acceleration section, the "Crandall cell", and finally the fringe field exit region.

The RFQ code TOUTATIS gives similar results.

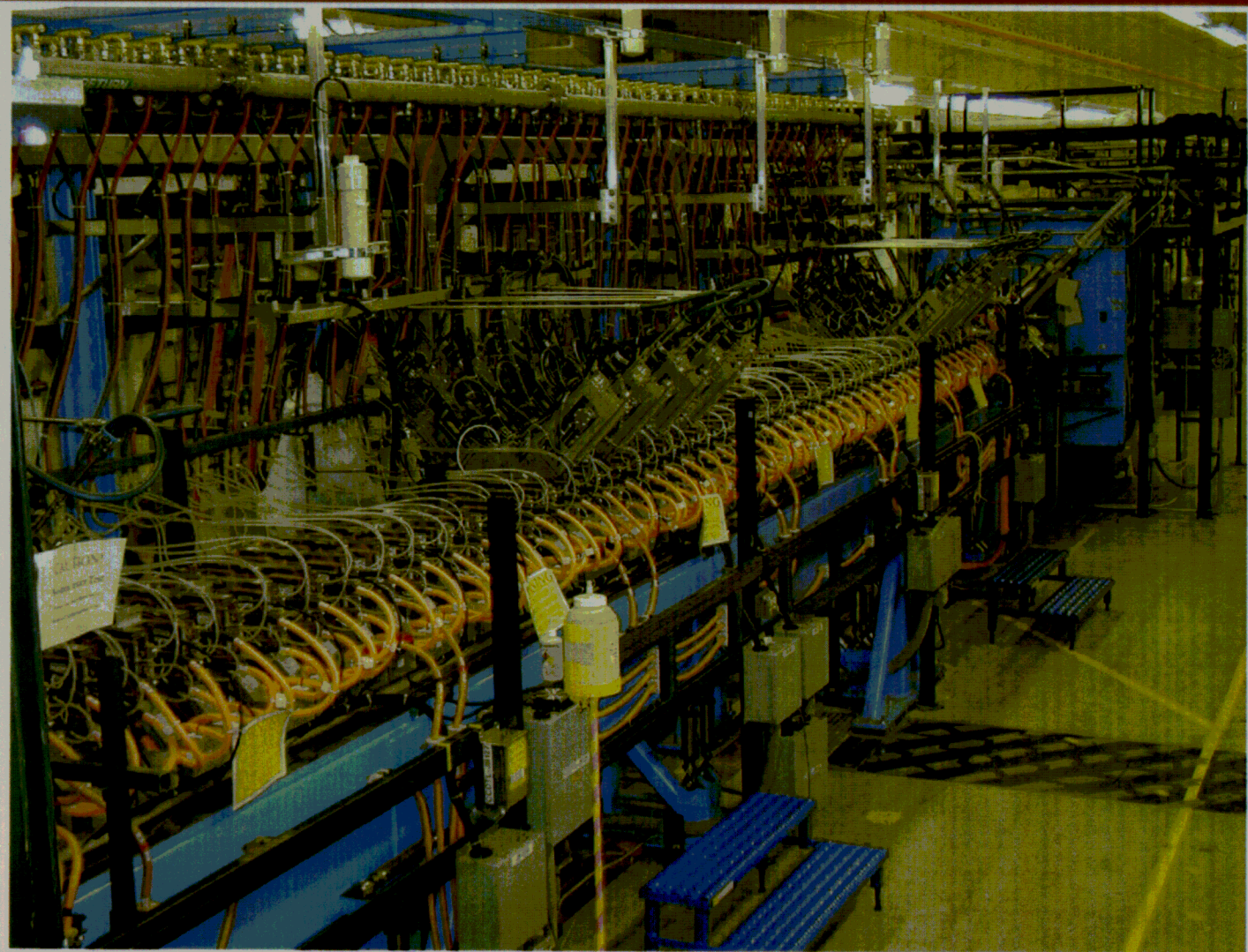
Fully Instrumented LEDA Beam-Halo Lattice



First 4 quadrupoles independently powered for generating mismatch modes.

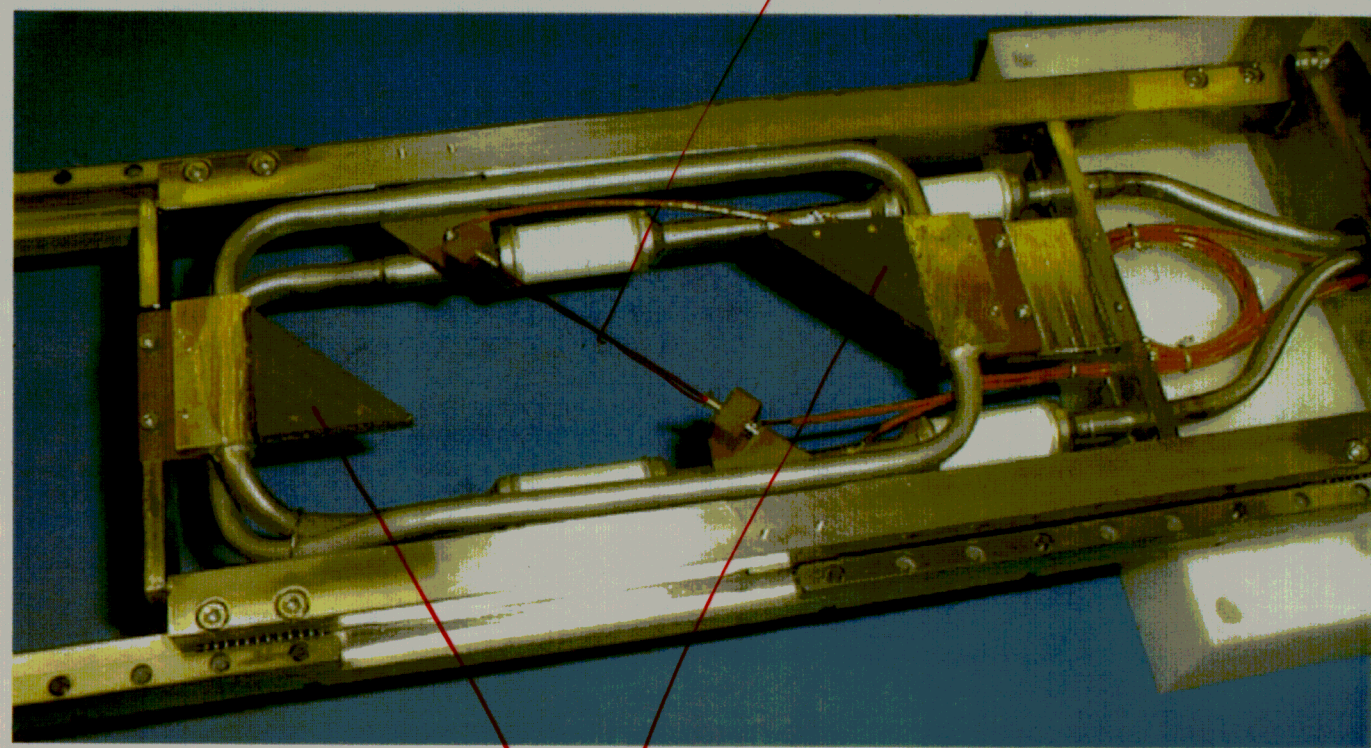
52 Quadrupoles + 4 in the HEBT
9 Wire Scanners/Halo Scrapers (Projections) + 1 in the HEBT
3 Toroid (Pulsed Current) + 2 in the HEBT
5 PMT Loss Monitors (Loss) + 2 in the HEBT
10 Steering Magnets + 2 in the HEBT
10 Beam Position Monitors (Position) + 5 in the HEBT
2 Resistive Wall Current Monitors (Central Energy)

LEDA Facility Halo Lattice



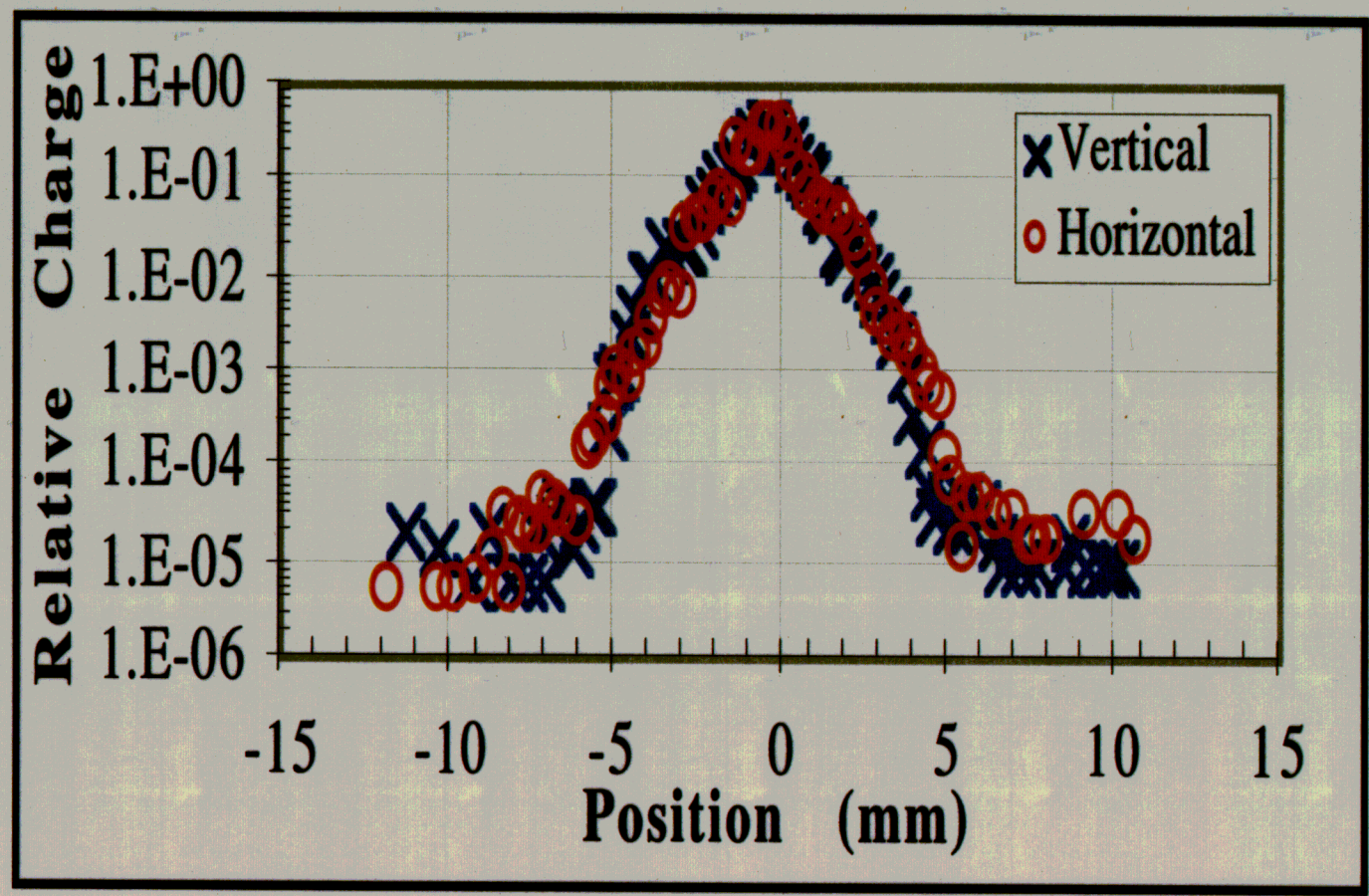
Close-Up of the Movable Frame of the Halo WS/HS Assembly

wire ⇒ core measurement



scrappers ⇒ halo measurement

Combined WS and HS Profile at Location #26: Spatially Differentiated, Averaged, etc.



HALO EXPERIMENT AT LOS ALAMOS

P. Colestock – D. Gilpatrick & al

1) MAJOR PROBLEM : knowledge of the FODO Channel input distribution

halo ⟶ halo

2) RMS emittance growth consistent with the Particle-core model + complete free energy transf

Fast : 10 core oscillations

3) Unexpected shoulders

"HALO FORMATION" UNDER ESTIMATED BY THE CODES

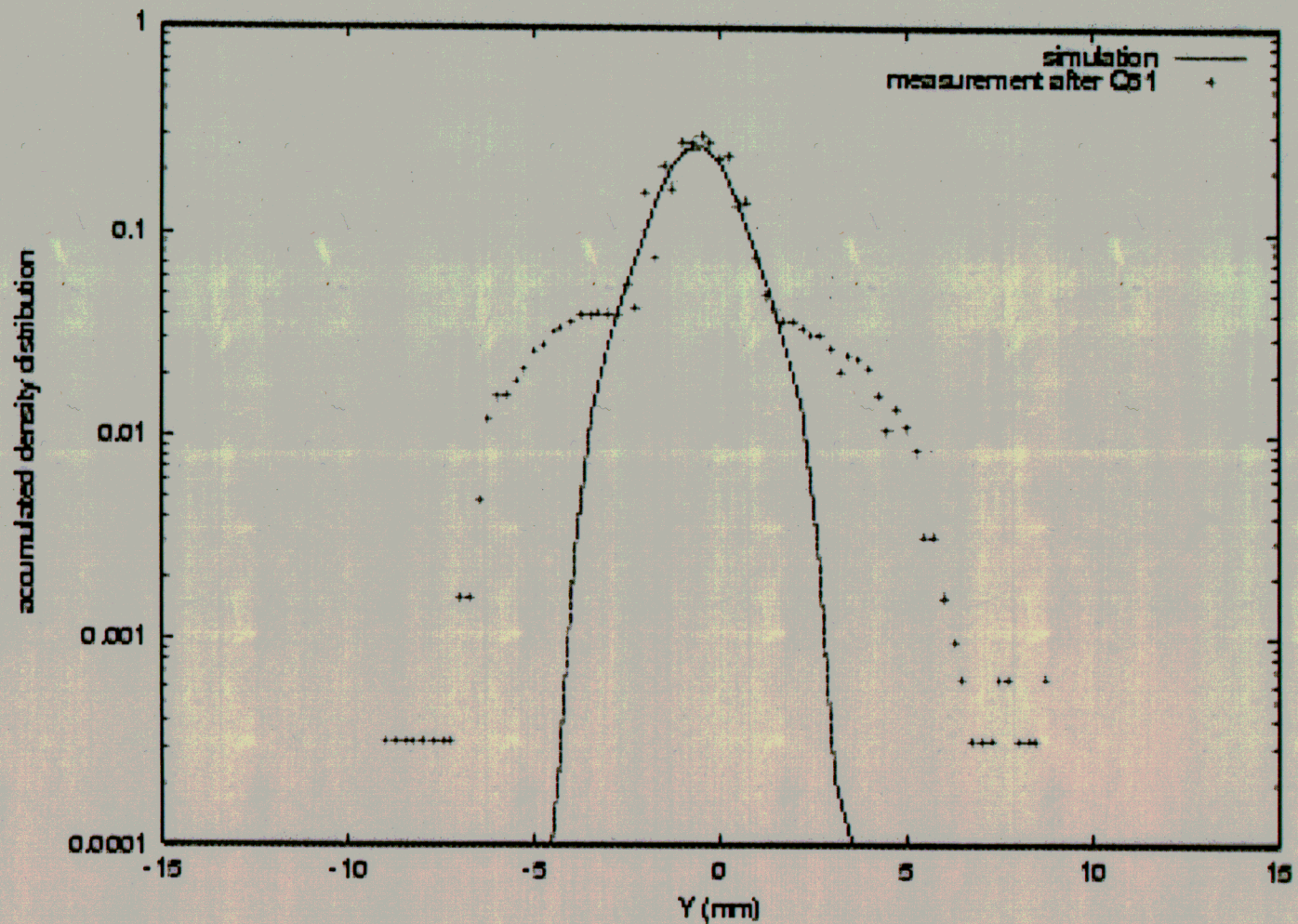
⇓

MORE EXPERIMENTS NEEDED

THE HALO EXPERIMENT MUST CONTINUE

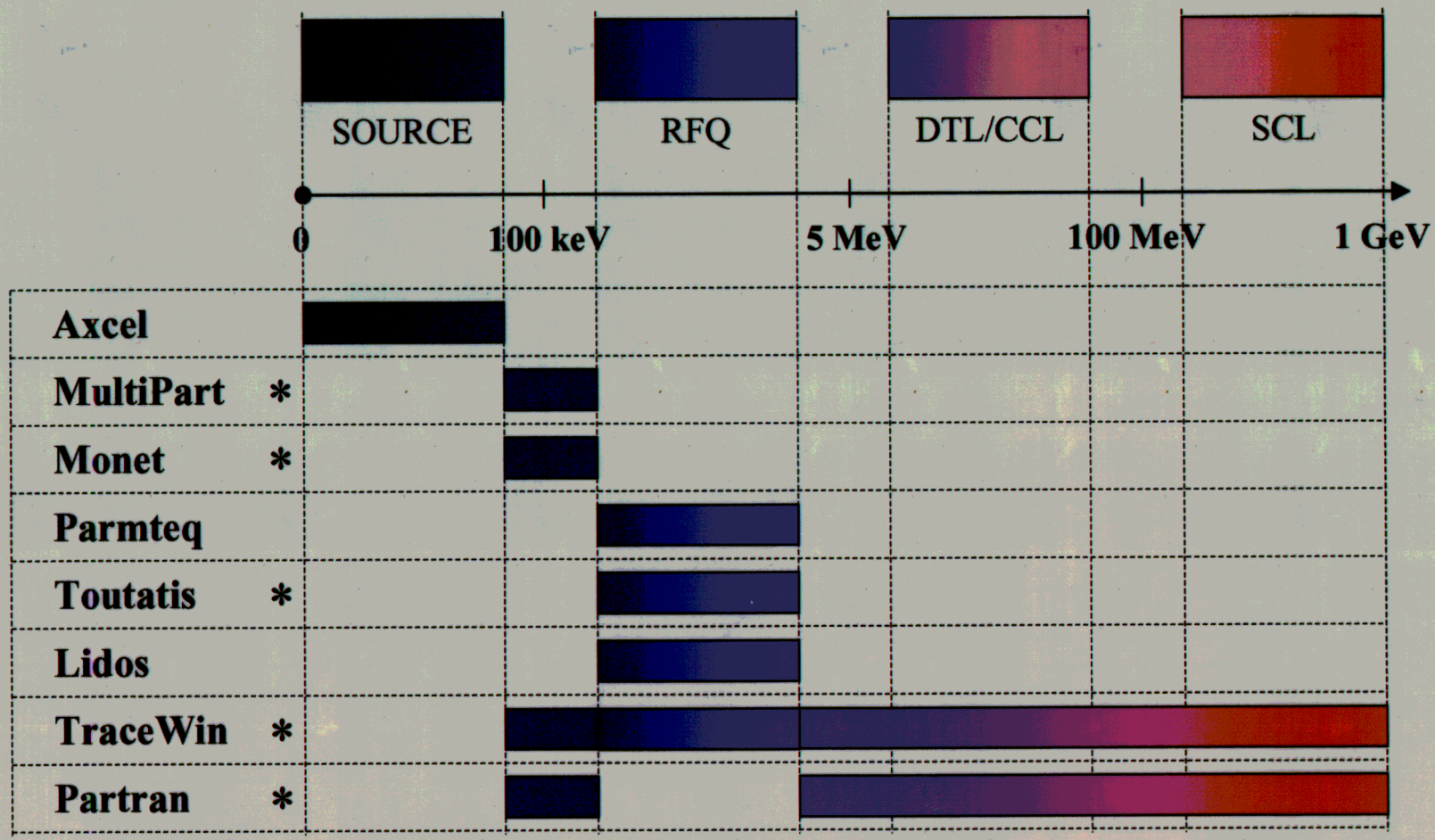
⇒ MUST BE SUPPORTED

Comparison of shape of measured profile (points) with simulation (curve) for mismatched case (μ=1.5) at scanner 51



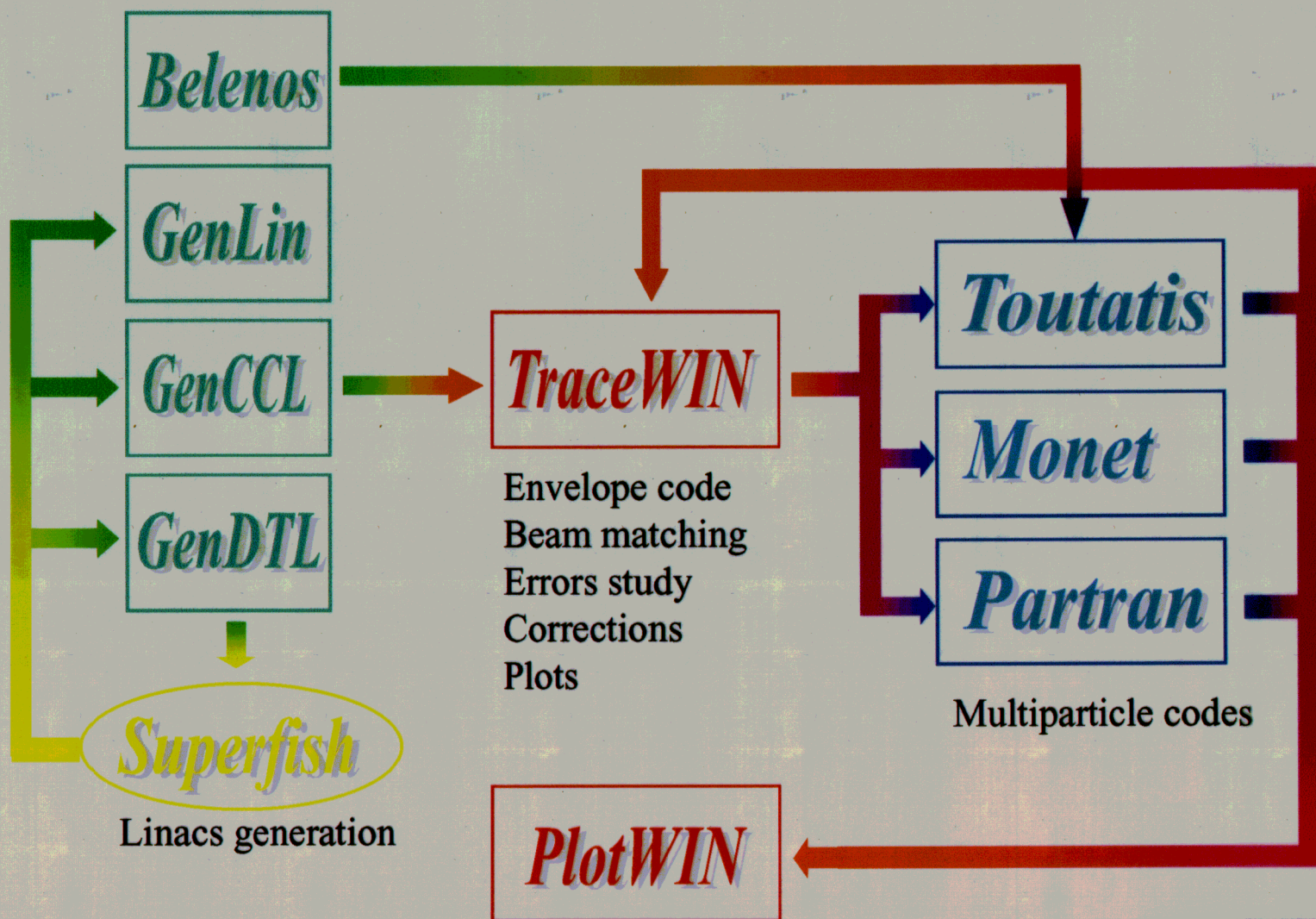
LINAC DESIGNS

Beam dynamics codes used in CEA



* codes written in CEA

Codes organisation



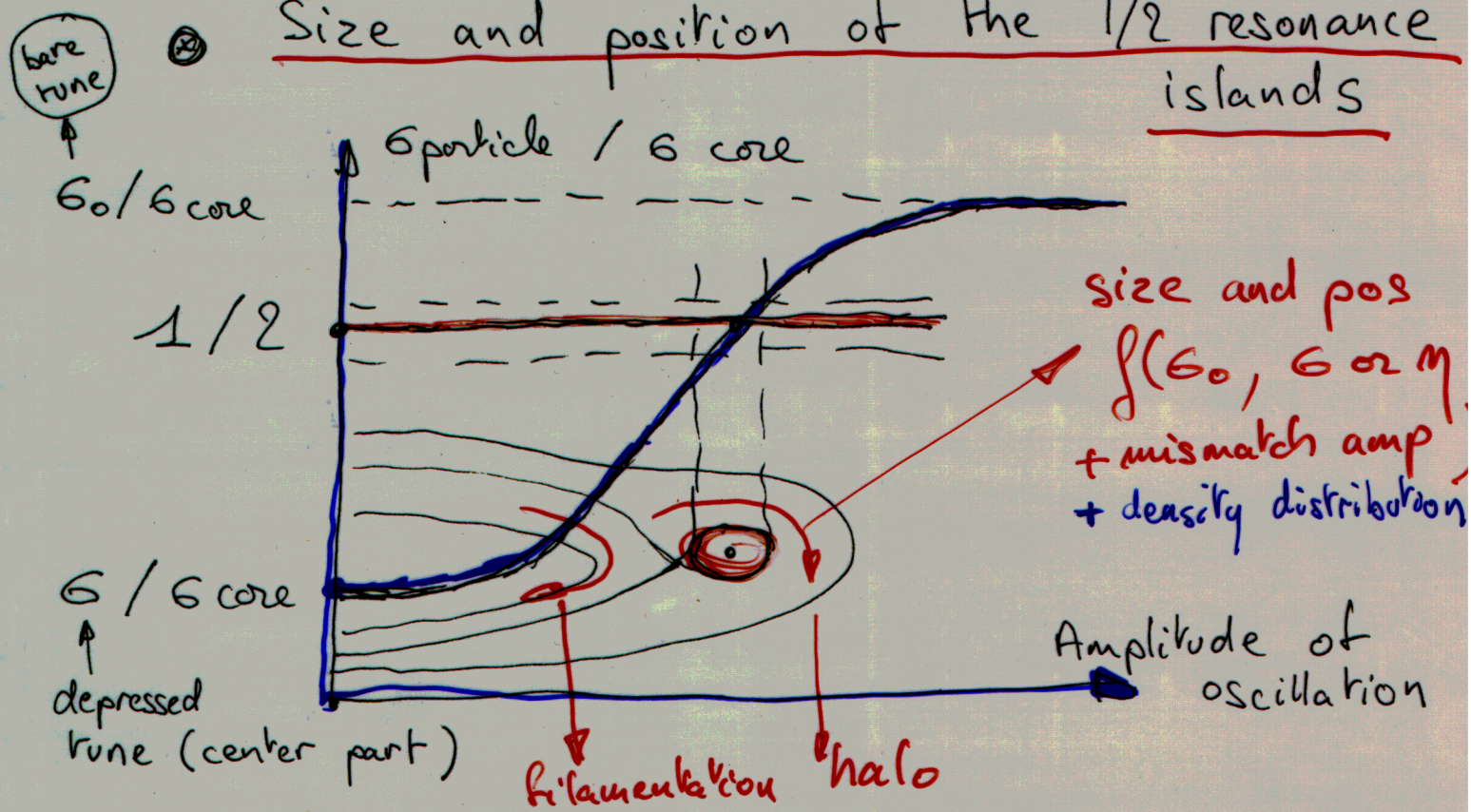
Example

MODELING OF MISMATCH AND ERROR INDUCED EMITTANCE GROWTH IN LINACS

Ingo HOFMANN and G FRANCHETTI

- 2D Numerical experiments

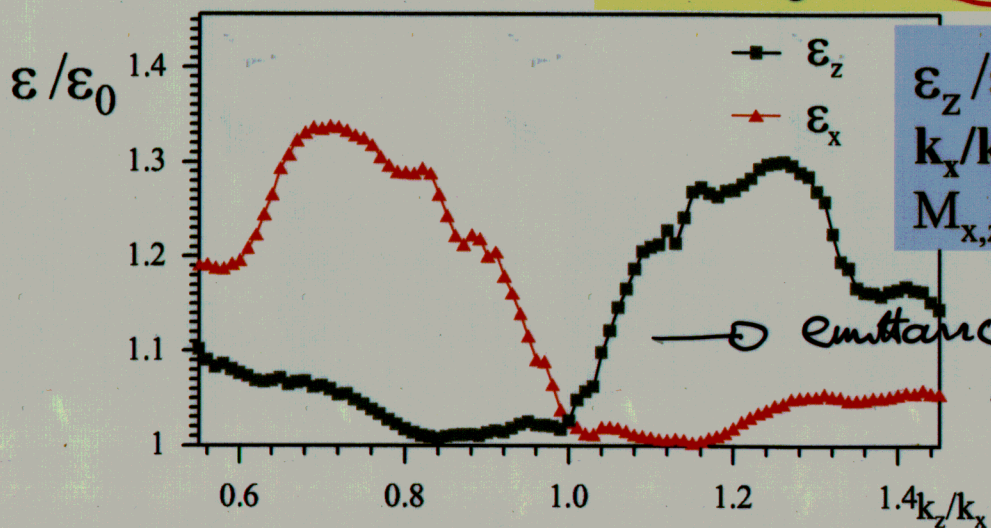
- Size and position of the 1/2 resonance islands



- Free energy concept vs end to end simulations

Rms emittance growth larger for stronger focusing direction = closer fixed-points

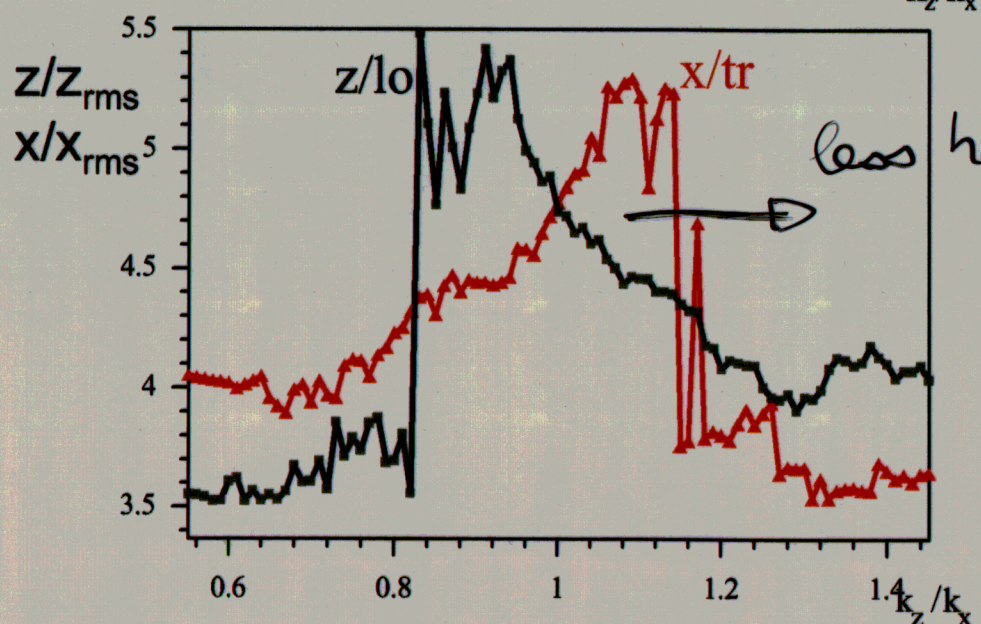
waterbag beam PIC simulation



$\varepsilon_z/\varepsilon_x=1$
$k_x/k_{0x}=0.6$
$M_{x,z}=1.3$

emittance increase in z

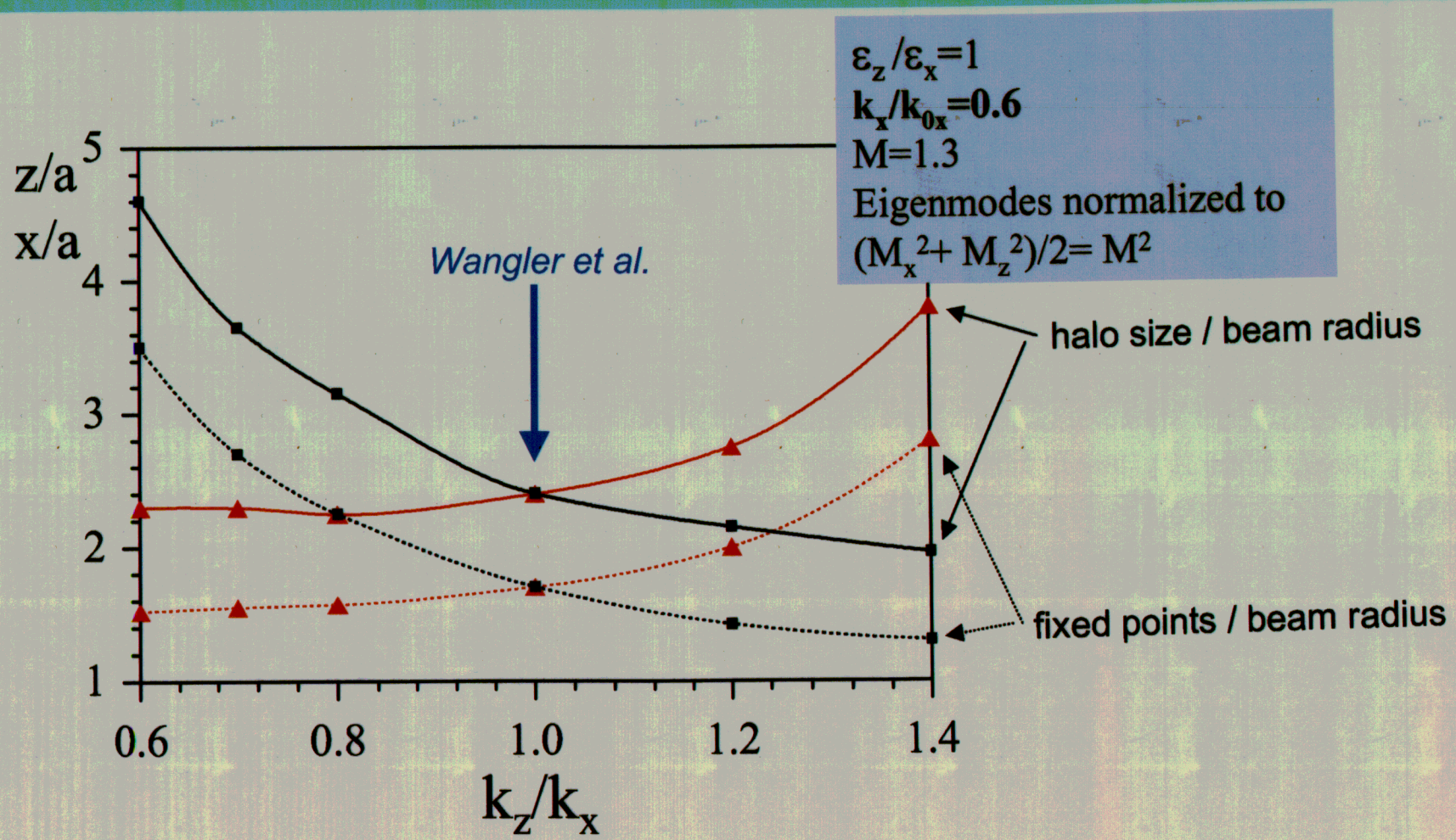
Anisotropic beam results from isotropic mismatch
„hotter" direction heated!
-> further away from EP



less halo in z

- Halo growth opposite to rms emittance growth
- No transport to resonance if fixed-point too far!
- Transverse halo larger for $k_z/k_x>1$

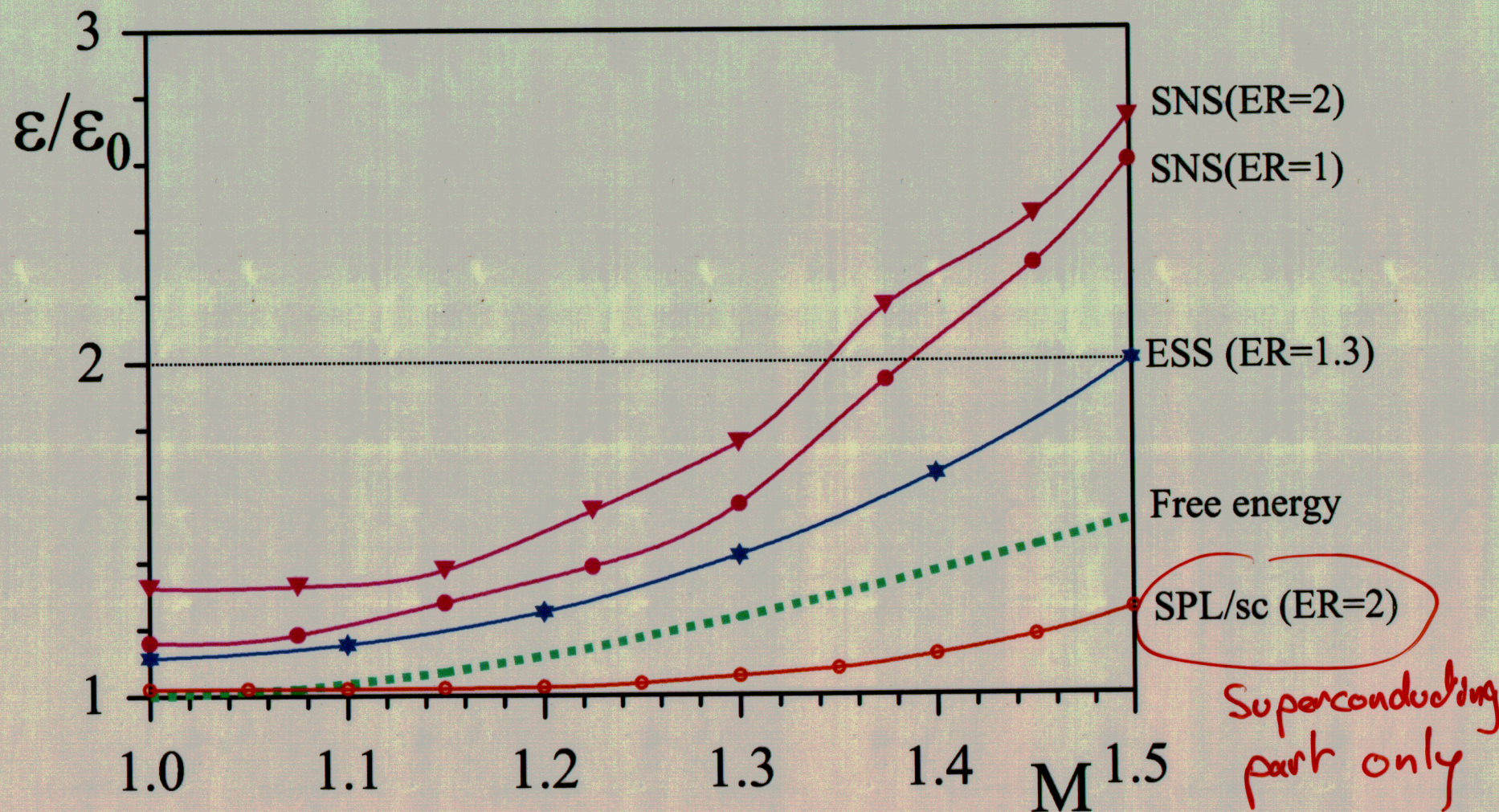
Confirmed by core-test-particle simulation for anisotropic beams



PARTICLE - CORE MODEL AGAIN A GOOD "TOY MODEL" TO UNDERTAND THE PHYSICS !

Comparison of $(\varepsilon_z + \varepsilon_x + \varepsilon_y)/3$ with "free energy limit"

assuming full conversion (symmetric mismatch in x,y,z)



ALL YOU WANT TO KNOW ON

Sources of emittance growth, halo or losses

- Bad design
- Mismatch
- Emittance exchange
- Interactions with residual gas
  - Scattering on Residual gas
  - Charge exchange
  - Space-charge compensation
- Magnetic stripping
- Linac errors

Mismatch-Filamentation

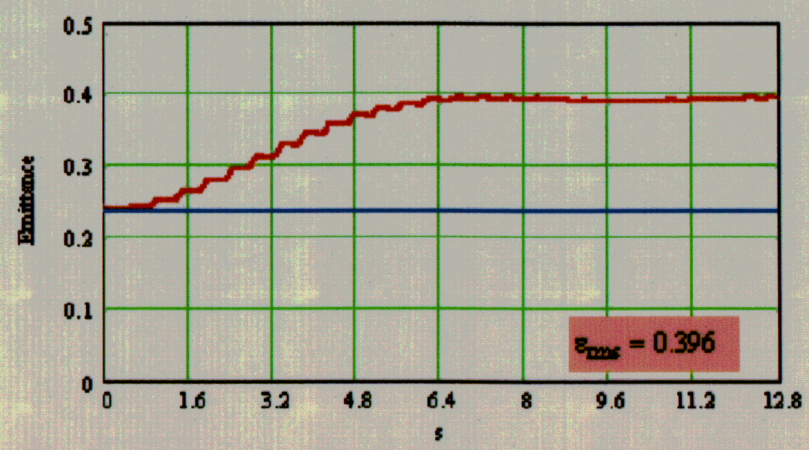
Non linear force : Particles do not oscillate with the same period

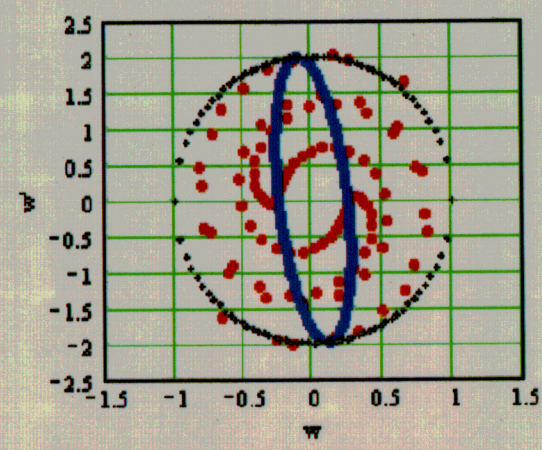
Space-charge : The largest the amplitude, the faster the oscillation.

Time scale : $Z \approx \frac{1}{2\cdot(1-\eta)}\cdot Z_0$ Z_0, the zero current period

Extension : Mismatch parameter M

when particles don't enter the 1/2 resonance islands





Linear force Non-linear force (space-charge)

PARTICLES TRAPPED IN THE

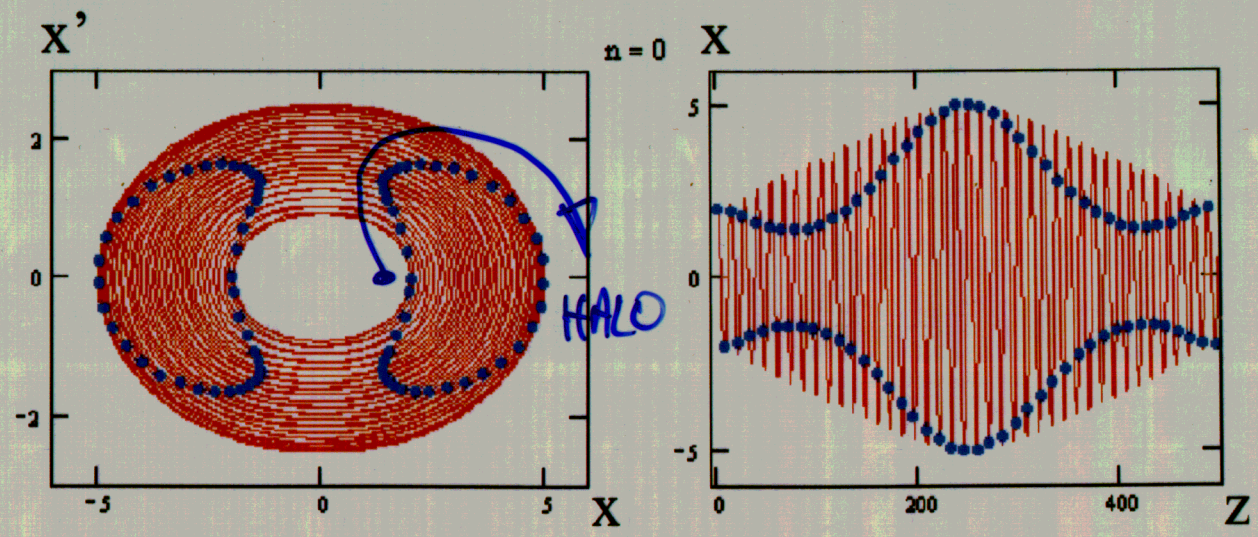
Resonance

ISLANDS (OR MOVE AROUND)

Particules oscillating with a period Z_p that is a multiple of a mismatch mode Z_m.

⇒ **Modulation of amplitude**

<u>Exemple</u> : Mismatch: M=30%; Depress tune: η=70%; Z_p/Z_m=1.92

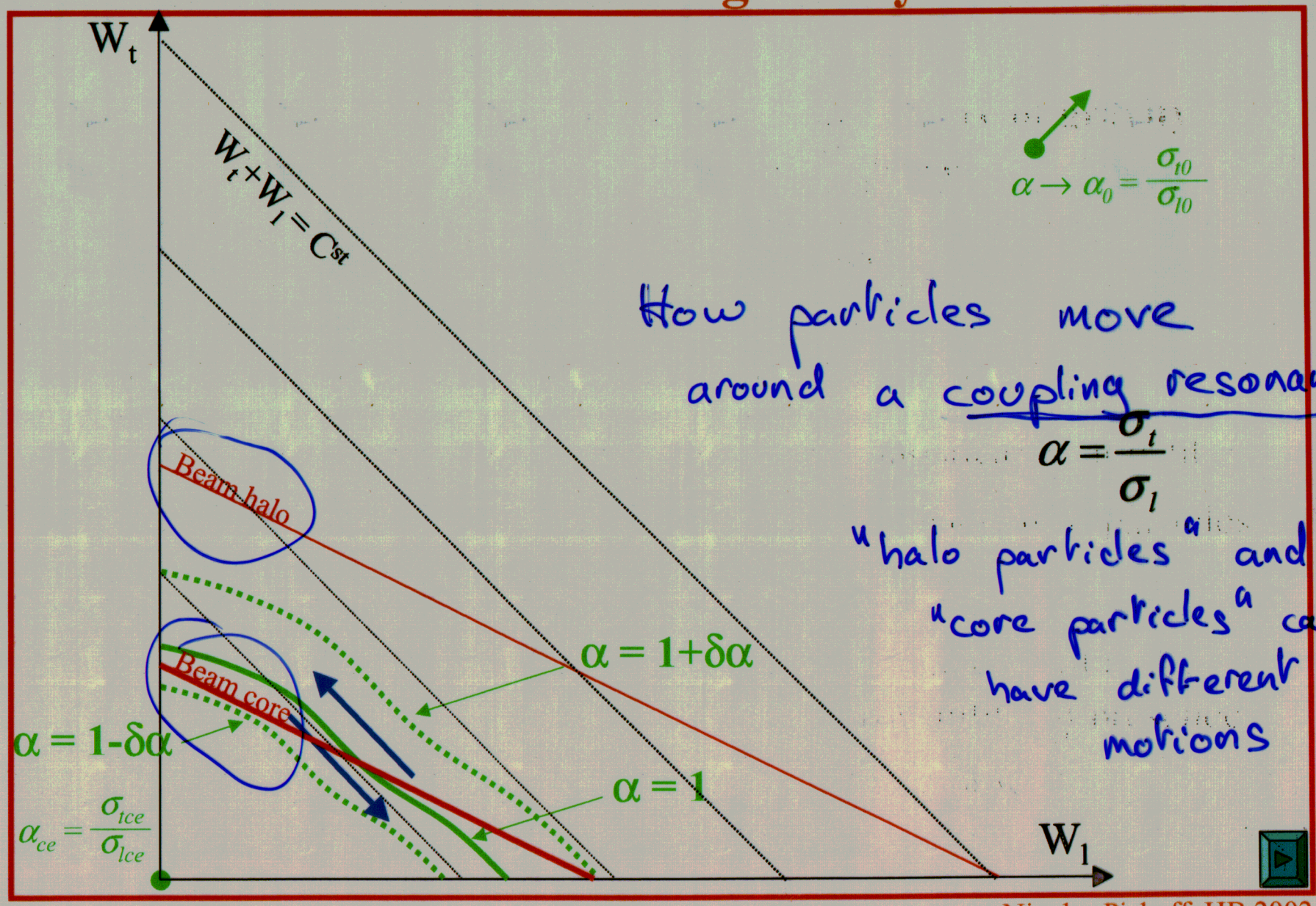


— Particle trajectory • Poincaré section

<u>Time scale</u> : Z = A few Z_0 Z_0, the zero current period

<u>Extension</u> : Much high than the mismatch parameter >> M

Emittance exchange : Physics?



How particles move around a coupling resonance

$$\alpha = \frac{\sigma_t}{\sigma_l}$$

"halo particles" and "core particles" can have different motions

2 hours / run for end to end simulations
1 week-end = 80 hours ⇒ 25 linacs with errors

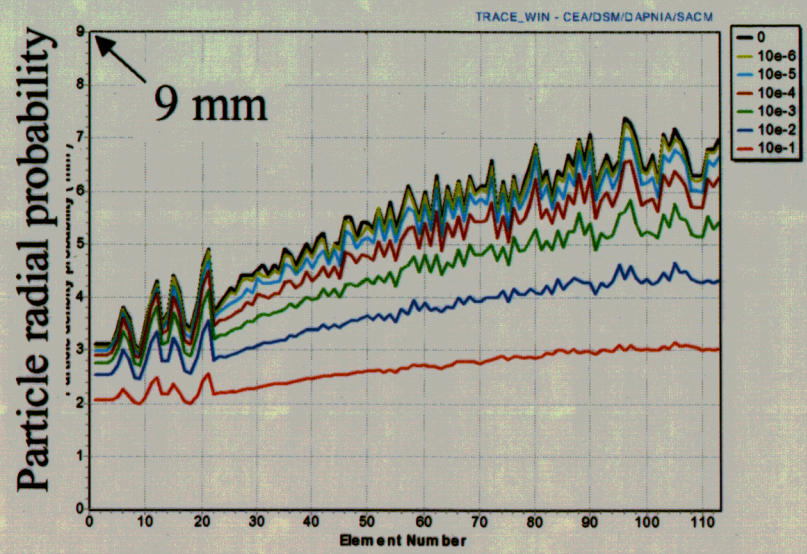
Linac errors

The clever guy uses 100 PC ⇒ 2500 linacs

The linac errors have an influence on beam centre of gravity displacement, mismatching and non linear forces.

Static errors : can be measured and corrected

Dynamic error : cannot be corrected



Longitudinal position

Statistical treatment :

n_l linacs of n_p particles

⇒ Calculus of a probability of presence