Space Charge Calculations at PSI

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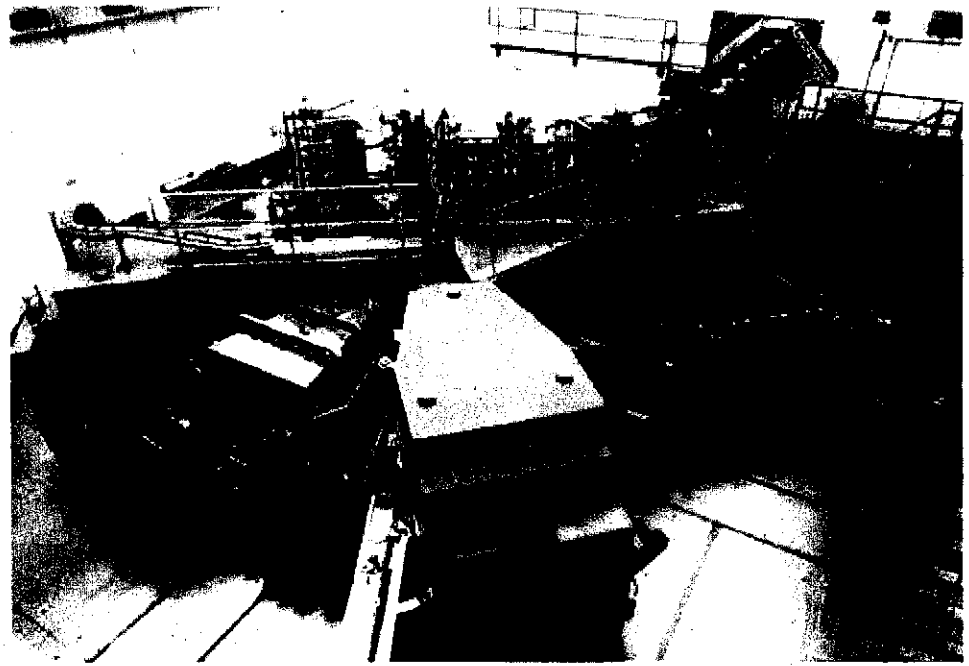
1. Introduction and Motivation
2. Mad9p
3. First Results & Future Plans

PSI PAUL SCHERRER INSTITUT

1. Introduction and Motivation

PSI proton accelerator
3 stage CW, 590 [MeV]
1.7 [mA] routine production
2.0 [mA] peak: 1.18 [MW]



Goal: 3.6 [mA] production

(around 2005)

Large Particle Simulations in complex structures are needed to predict uncontrolled beam loss

Space Charge at PSI:

- *Analytic studies*
- *Numerical 2D Model*

Workshop on Critical Beam-Intensity Issues in Cyclotrons

1995 Santa Fe

3D Space Charge calculations:

- large range of scales

- nonlinear

- N: 10^9 ... 10^14 ....

2. Mad9p

Initial Conditions → M → Final Conditions

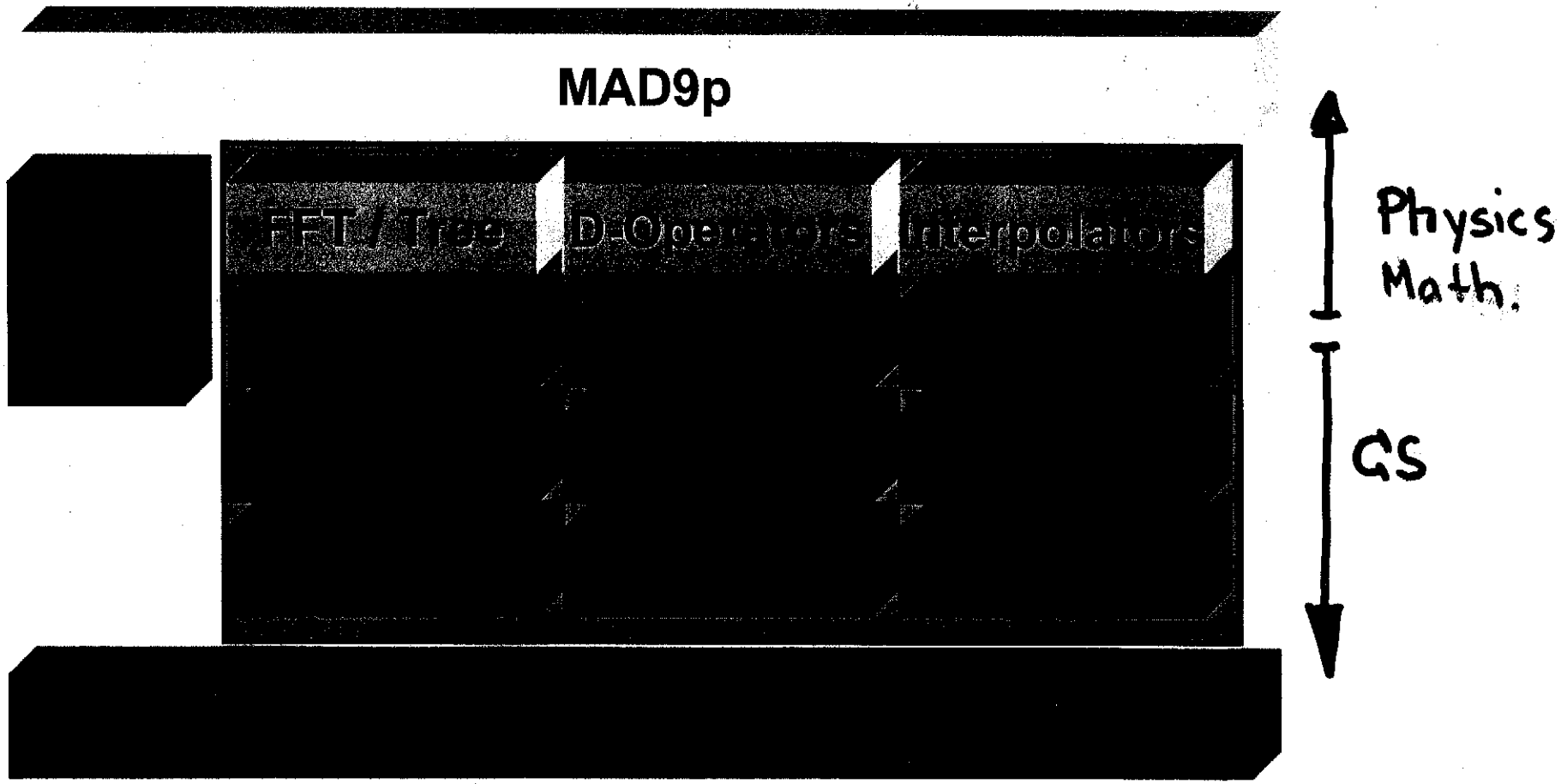
Lie Algebraic Methods

$$H = H_{ext} + H_{sc}$$

Parallel 3D Poisson Solver

$$M(s) = M_{ext}(s/2)\, M_{sc}(s)\, M_{ext}(s/2) + O(s^3)$$

MAD9p

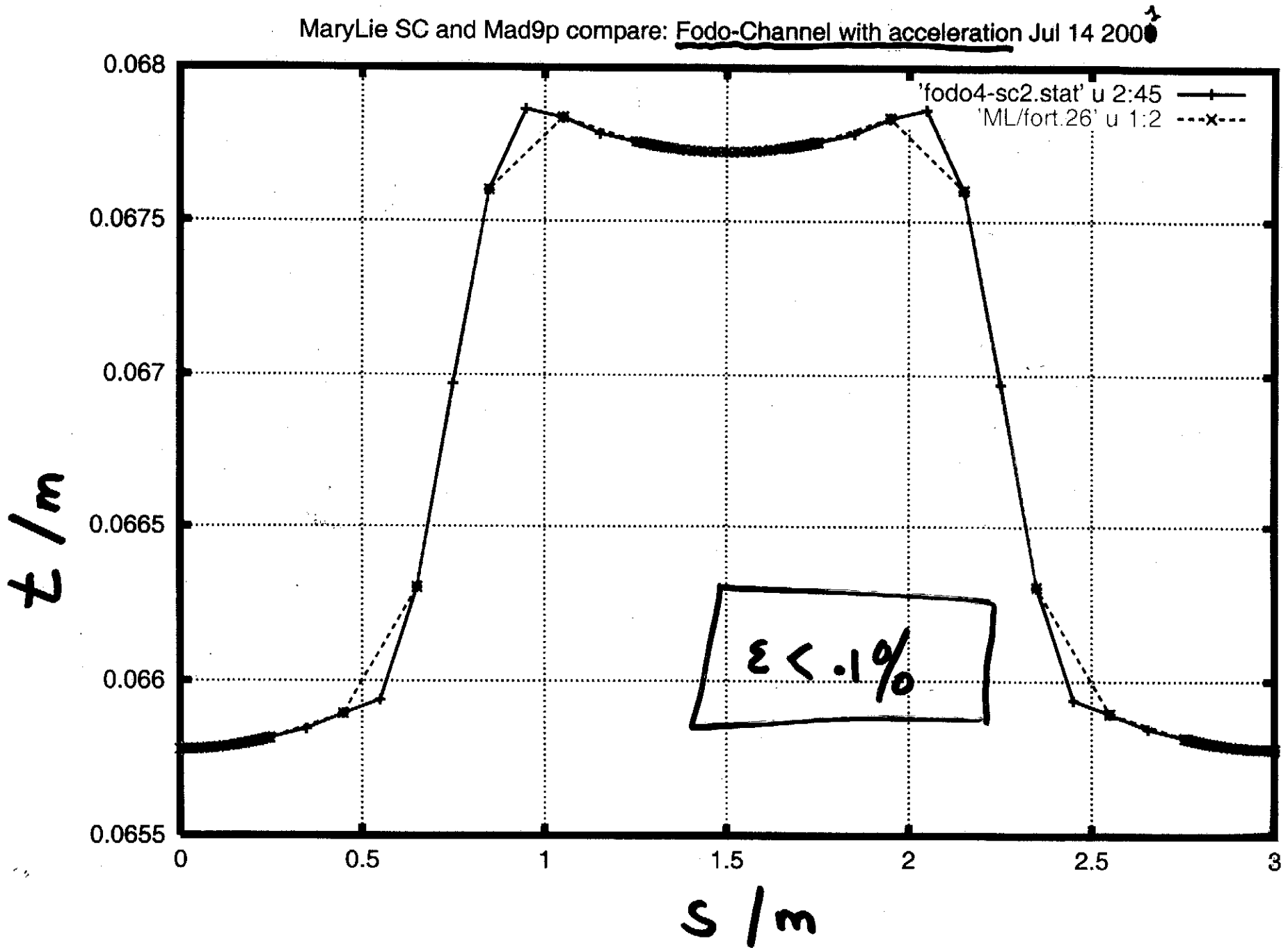


POOMA Parallel Object Oriented Methods and Applications

MAD Methodical Accelerator Design

CLASSIC Class Library for Accelerator Simulation System and Control

3D RMS Env.


MaryLie SC and Mad9p compare: Fodo-Channel with acceleration Jul 14 2000
'fodo4-sc2.stat' u 2:45
'ML/fort.26' u 1:2
0.068
0.0675
0.067
0.0665
0.066
0.0655
0
0.5
1
1.5
2
2.5
3
t /m
s /m
ε < .1%

3. First Results & Future Plans

- **870 keV Injection Beamline**
- **Coasting Beam**

- **CERN Neutrino Factory**

Parametos:

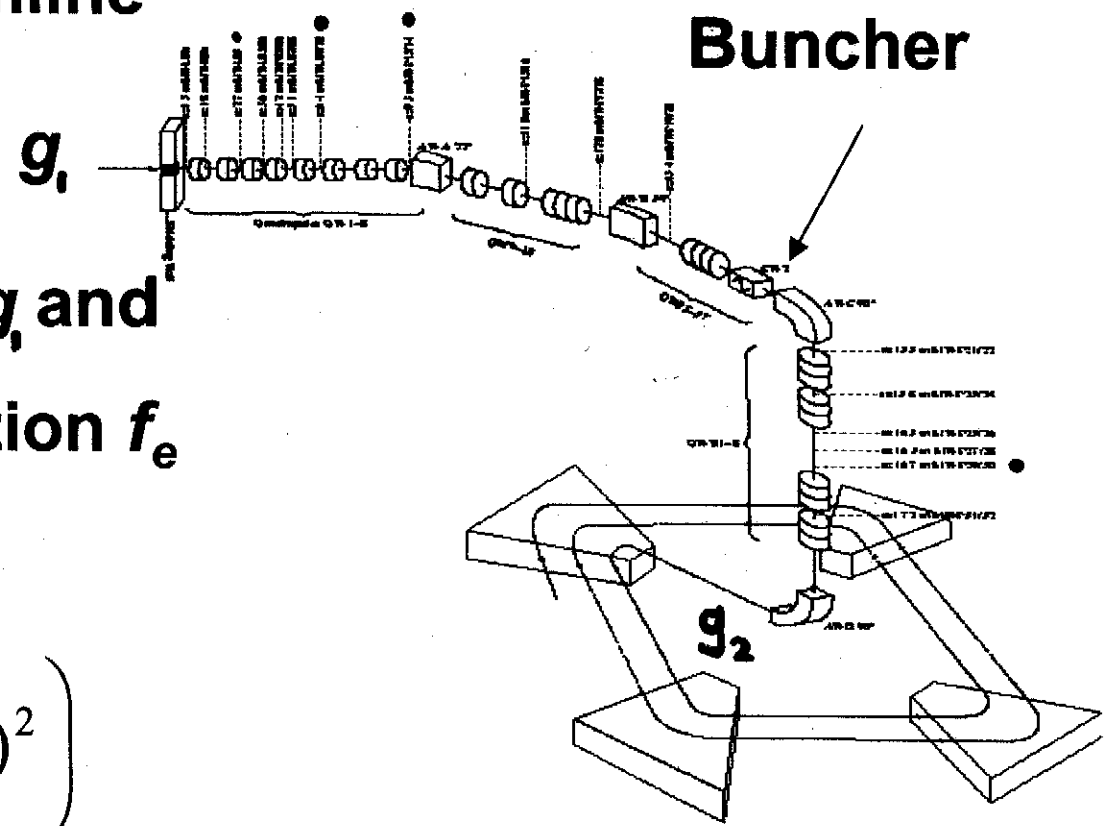
N: $10^7 \ldots 10^8$

M: $256^2 \times$ ~~2048~~ 4096 , 512^3

P: $16 \ldots 256$

Linux, SGI, IBM SP-2

- **870 keV Injection Beamline**

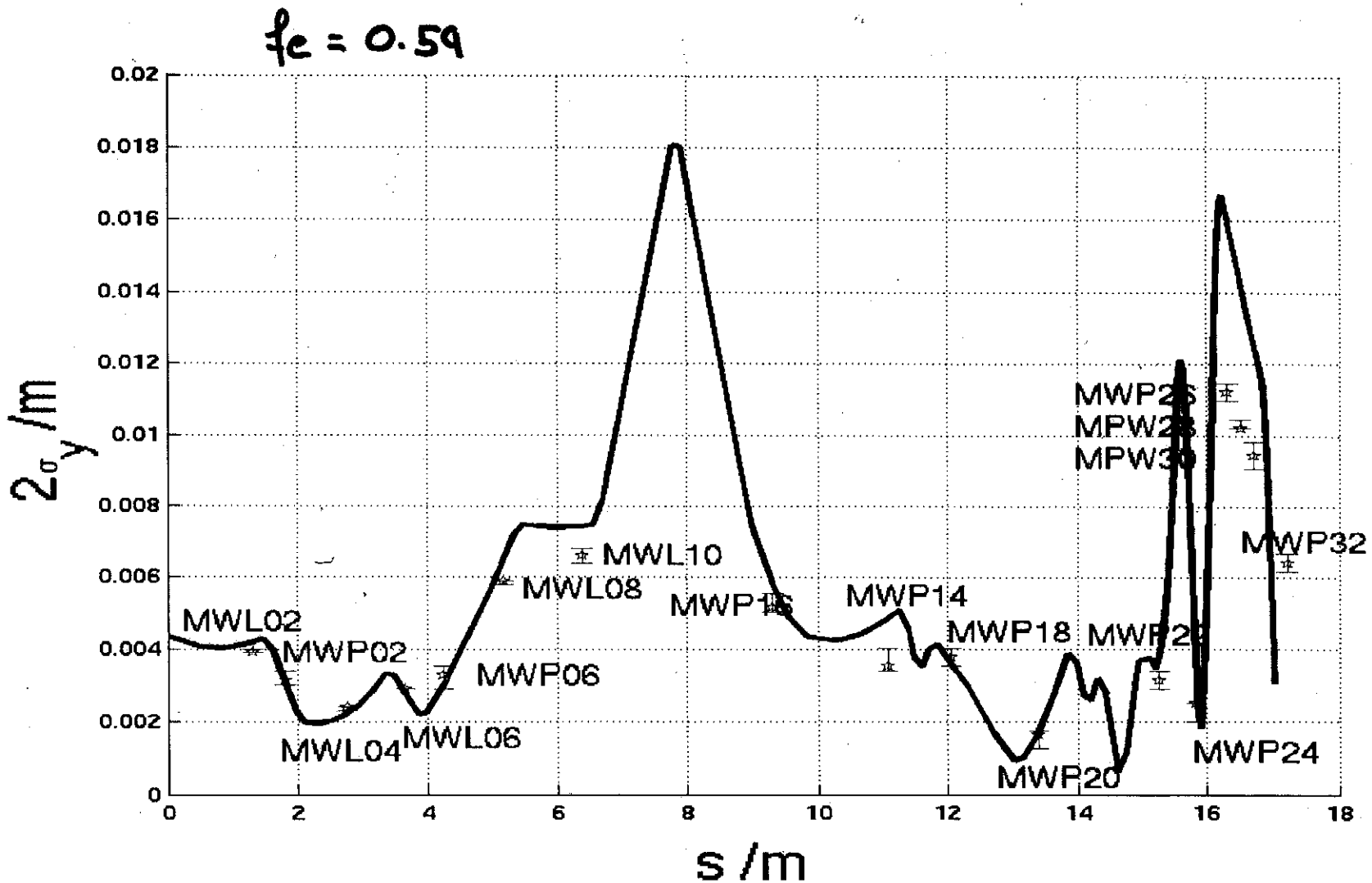


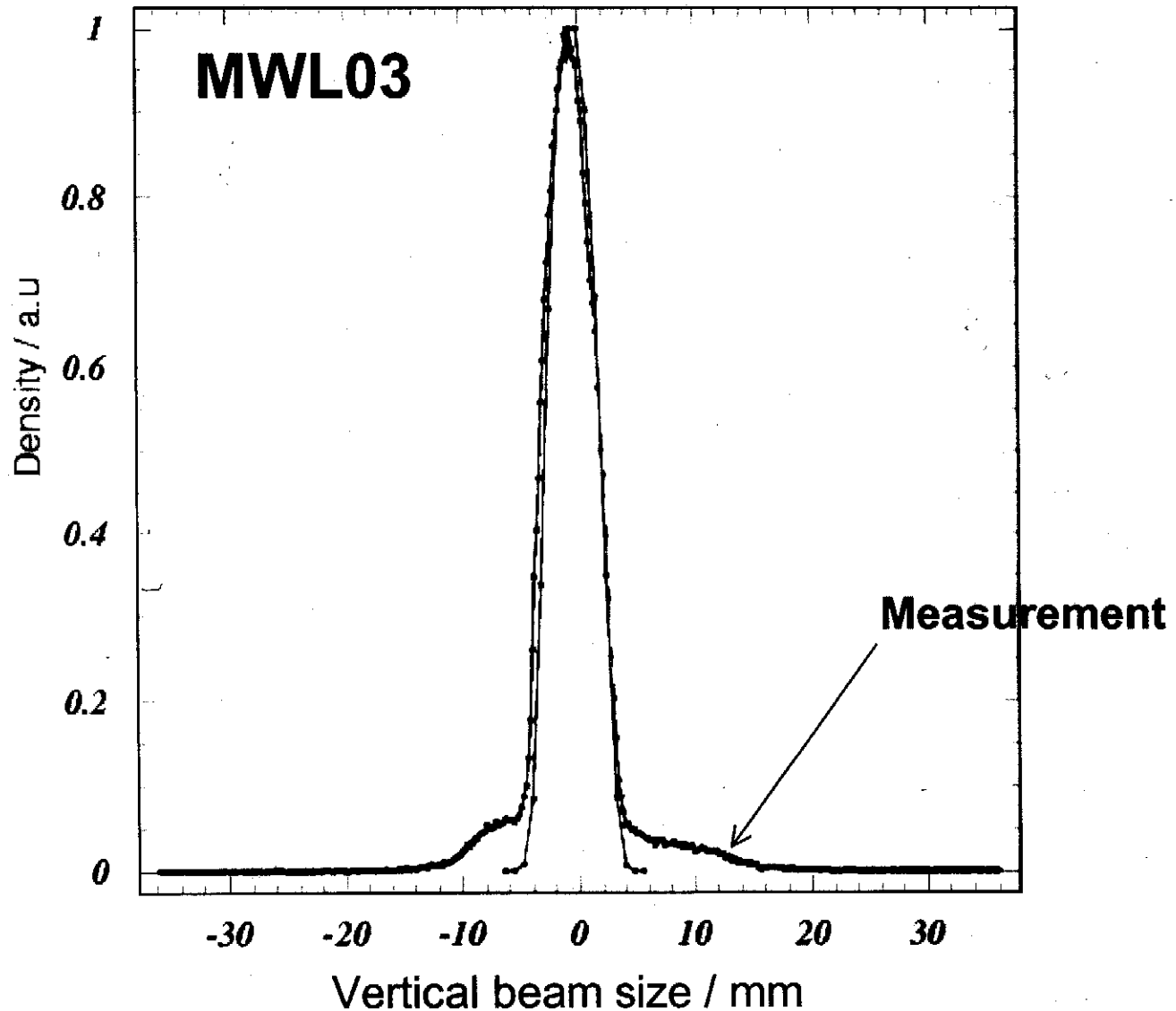
Find initial distribution g_1 and space charge neutralization f_e

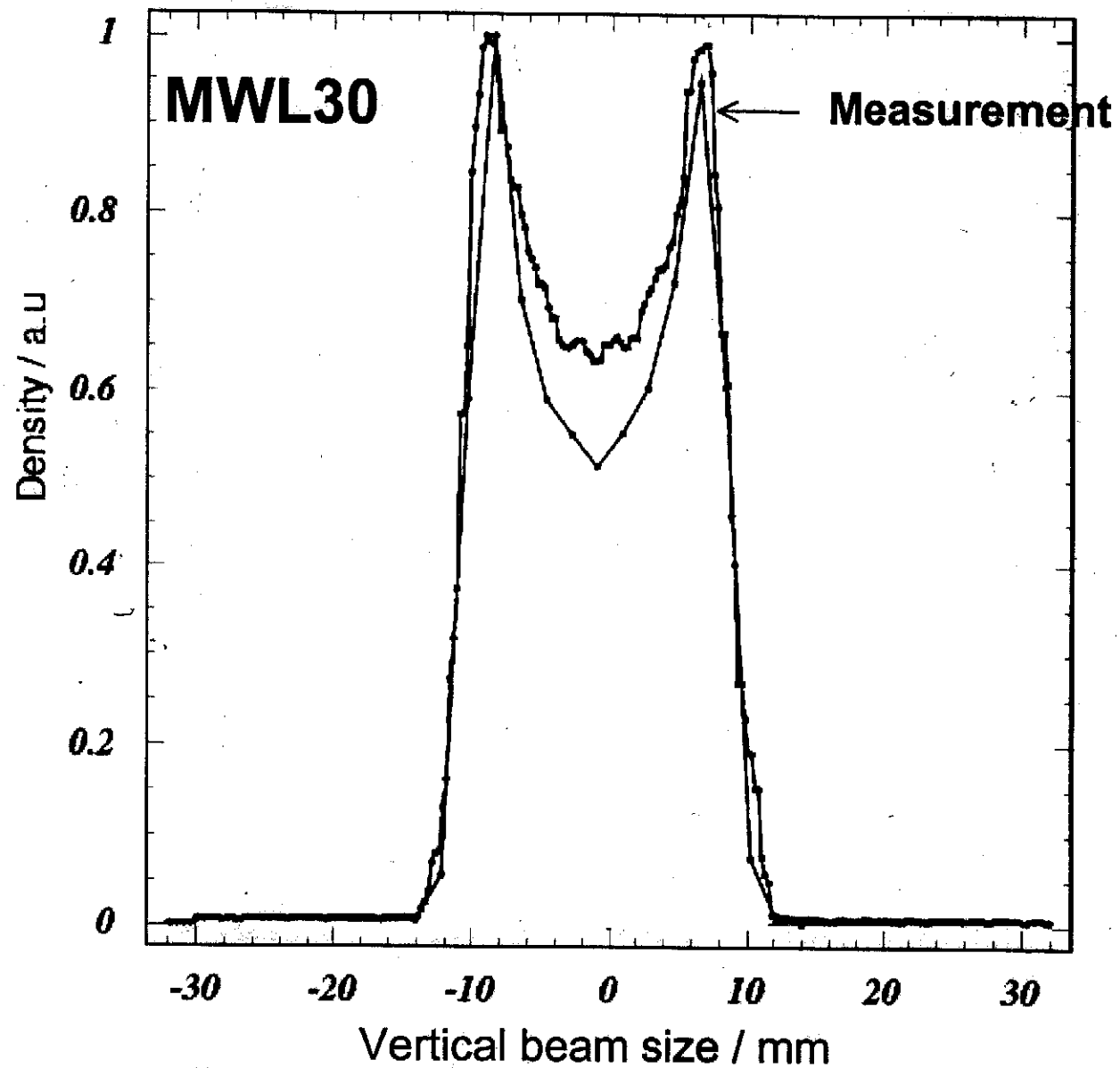
by

$$\Delta = \min\left(\sum_{\forall \text{ Monitors}} (x_{\text{meas}} - x_{\text{calc}})^2 \right)$$

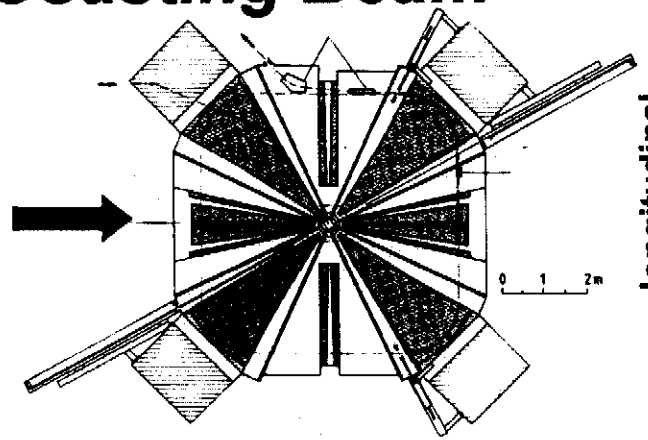
using Simulated Annealing.

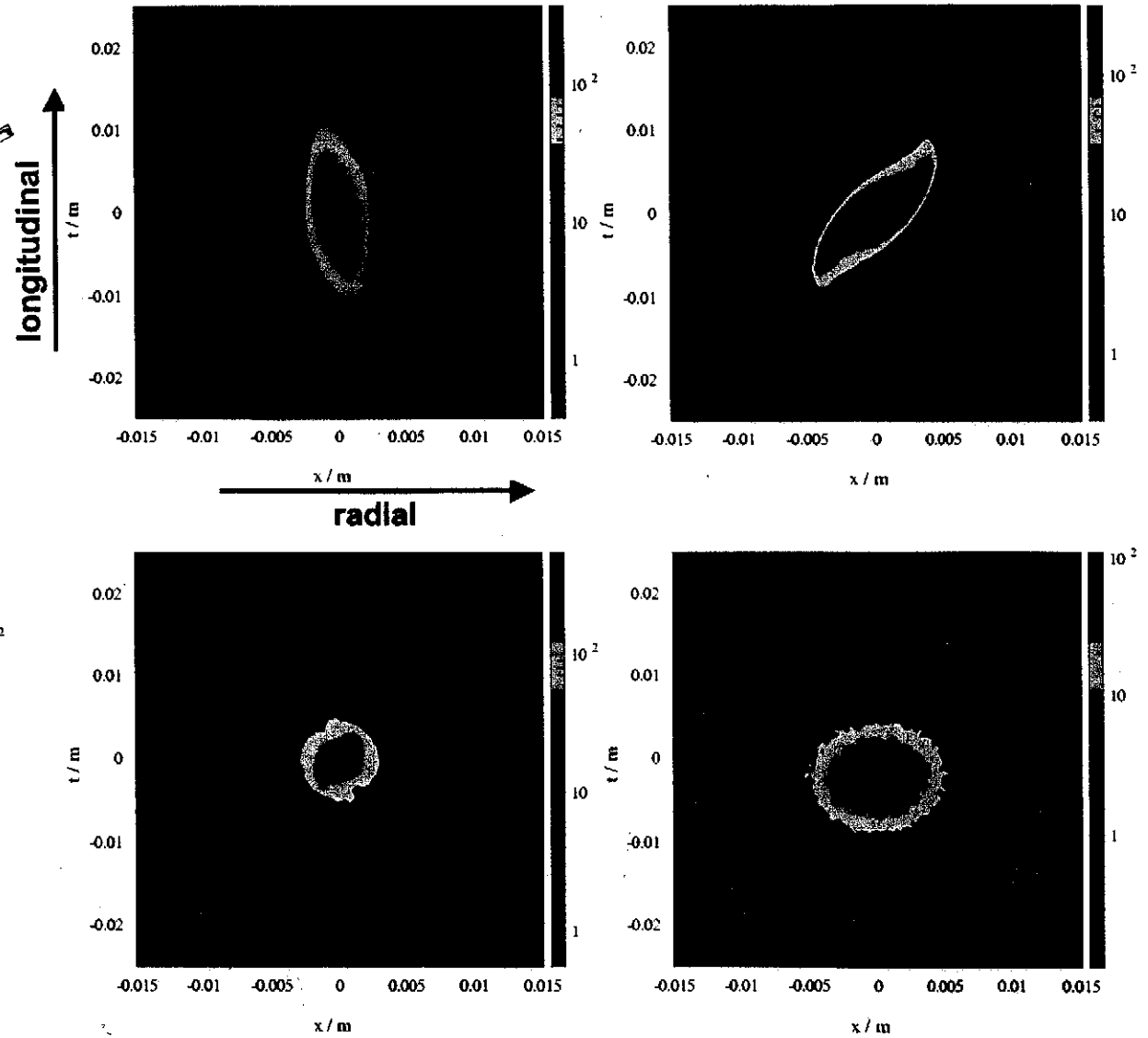

fc = 0.59
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
$2\sigma_y$ /m
0
2
4
6
8
10
12
14
16
18
s /m
MWL02
MWP02
MWL04
MWL06
MWP06
MWL08
MWL10
MWP14
MWP18
MWP20
MWP24
MWP32


MWL03
Measurement
Density / a.u
1
0.8
0.6
0.4
0.2
0
-30
-20
-10
0
10
20
30
Vertical beam size / mm

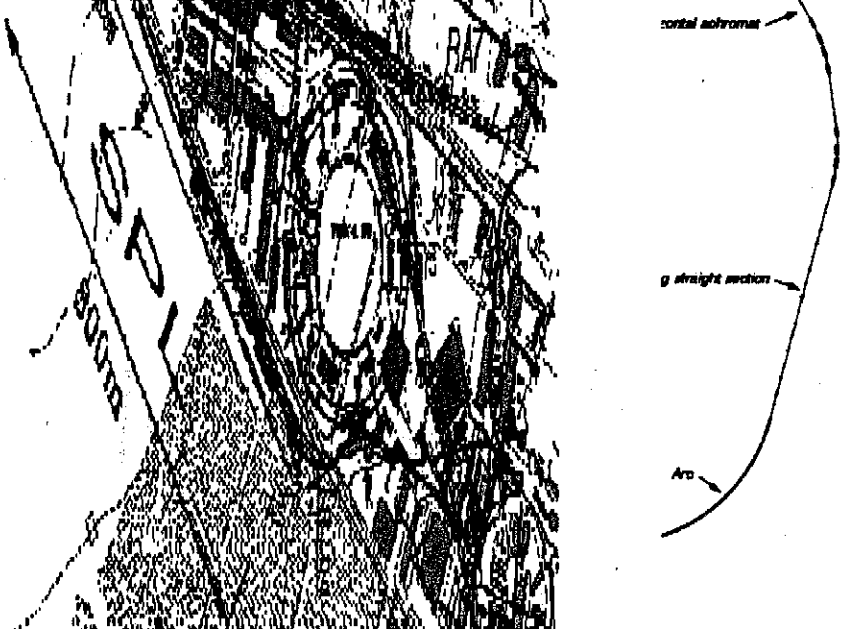

MWL30
Measurement
Density / a.u
1
0.8
0.6
0.4
0.2
0
-30
-20
-10
0
10
20
30
Vertical beam size / mm

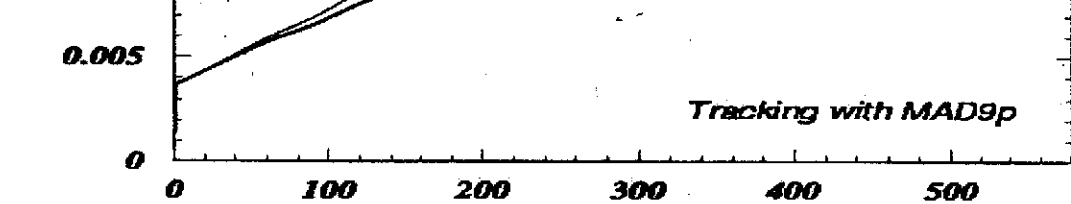
Coasting Beam

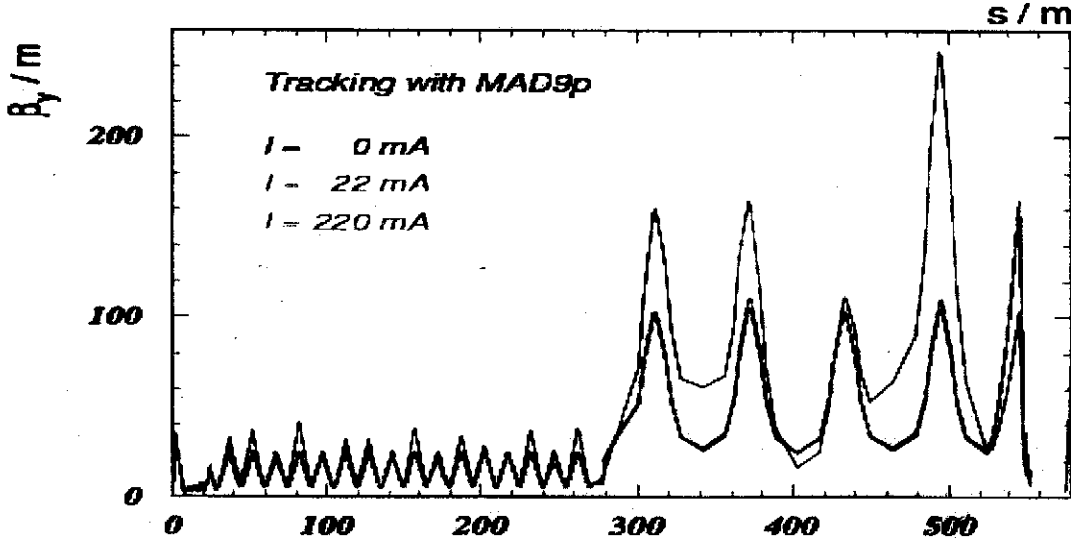




CERN ν–Factory Design Study







Summary

- **Concept-1: general 3D particle tracker with Space Charge**
- **Concept-2: parallel, OO-Framework, platform independent**

Future

- Implement/study different field solvers in a given context
- More physics: residual gas, multi species
- General BC

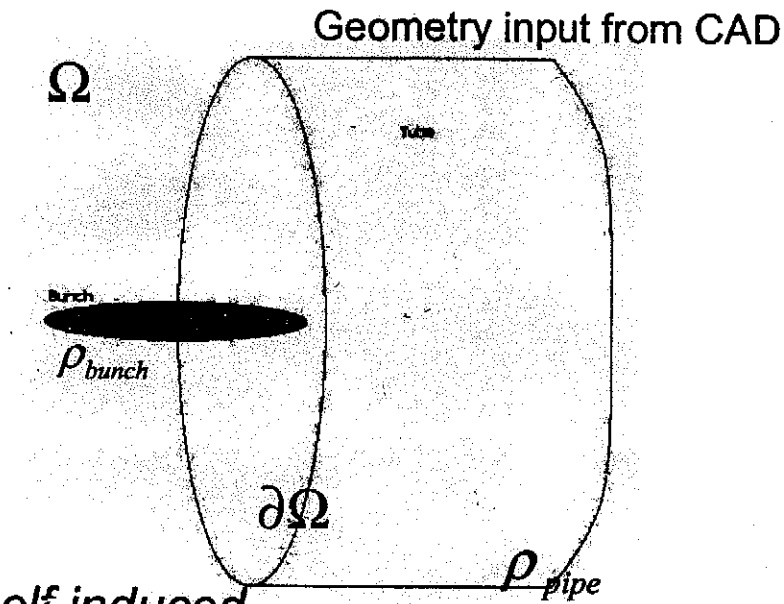
- Injector 2 incl. acceleration
- ν-Factory storage ring

General Boundary Conditions

1. We have:

$$\tilde{\Phi}(x) = 0, |x| \to \infty$$

$$\tilde{\Phi}(x) \neq 0 \ on \ \partial\Omega$$



2. Solve for additional $\rho_{pipe} = \Delta A \sigma$ so that the self induced potential is equal to:

$$-\tilde{\Phi}\Big|_{\partial\Omega} = \iint_{Tube/Surface\ A} \sigma(r') \frac{1}{4\pi\varepsilon_0 |r - r'|} dA'$$

3. Solve for the correct potential

$$\Delta\Phi(x) = -\frac{\rho_{bunch} + \rho_{pipe}}{\varepsilon_0} \ in \ \Omega \subset \Re^3$$

Which yield $\Phi(x) = 0 \ on \ \partial\Omega$ because of linear PDE