Activities of the "Theory and Simulation" group

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June 11, 2003
Talk given to the collaboration
Columbia University

Theory and Simulation Board

The charge for this committee is here

R. Raja (FNAL)	Chair	raja@fnal.gov
H. Kirk (BNL)	Targetry Simulation Co-ordinator	kirk@bnl.gov
R. Fernow (BNL)	Phase Rotation Simulation Co-ordinator	fernow@bnl.gov
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Charge to The Theory and Simulation Board

The committee will meet periodically to review simulation and theory progress, set priorities, and make plans to further this work. Minutes should be kept to document the main conclusions from the discussion

The committee will include the leaders of the simulation sub-groups covering:

- Target
- Phase Rotation
- Cooling and Emittance Exchange
- Acceleration
- Theory

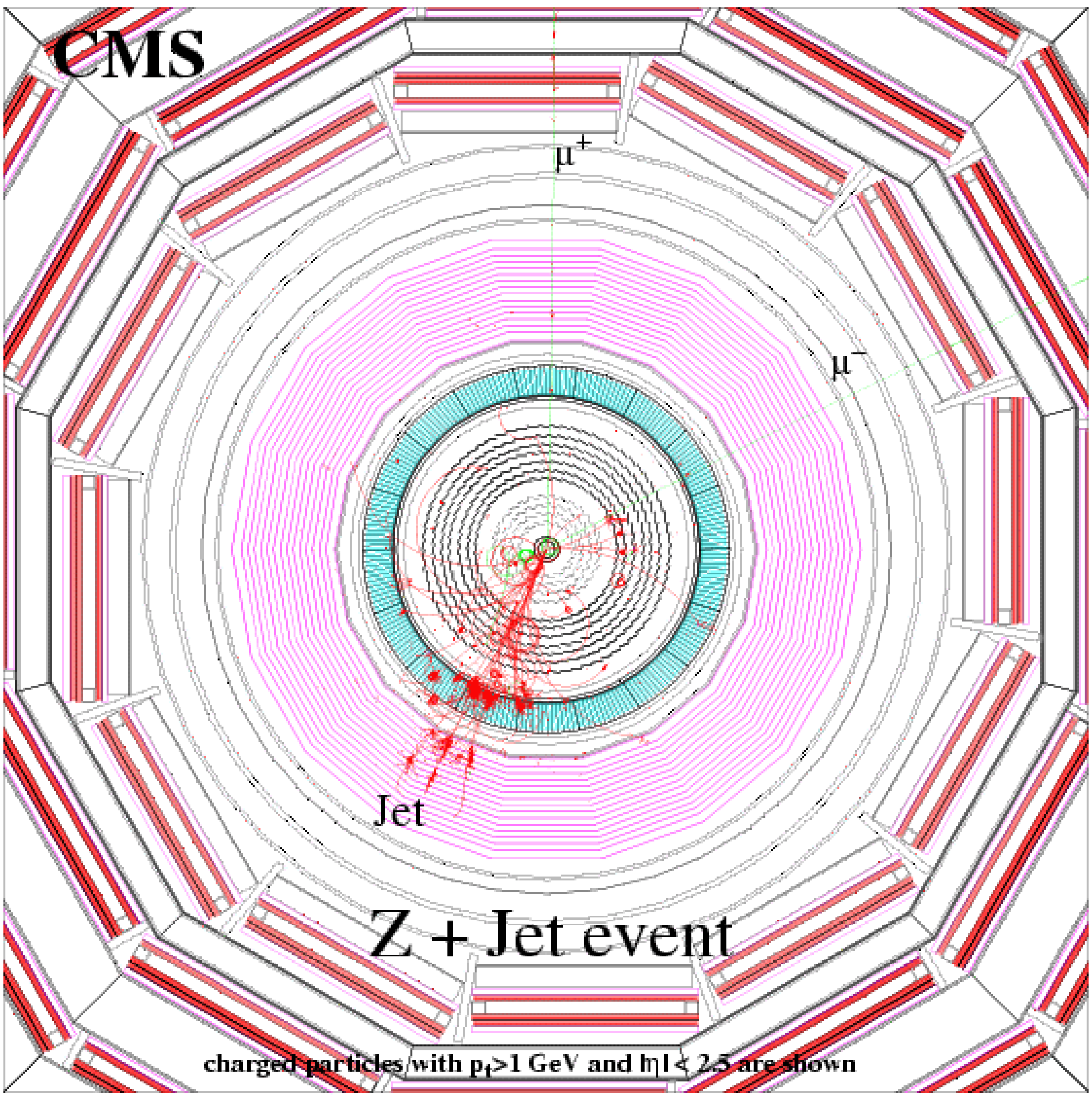
These subgroup leaders plus a few other members will be chosen by the chairman of the committee in consultation with the MC Spokesperson(s).

The committee should:

1. Assure that each Sub-group holds workshops with the appropriate frequency.
2. Co-ordinate proposals to use collaboration funds for post docs and visitors doing simulation work. The committee chairperson will present these proposals to the Technical Board at the appropriate time each year.
3. Advertise, interview and select Post-Docs and visitors for any open positions approved by the MC Spokesperson(s), and make a recommendation of where best they should be based and the topic(s) they should work on.
4. Maintain a list of all people within the MC contributing to simulation and theory activities, and identify which areas they are contributing to.
5. Consider any other activities that might further simulation and theory work.

December 10, 2002.

Geant Geometry- Complex example- CMS detector



Geant geometry

- Can simulate complex absorber shapes easily. Can calculate deposition of energy due to dE/dx of muons + decay electrons accurately. Can make the simulation very realistic. Needed before building.
- Also, magnetic fields are described as field maps (not expansions about the closed orbit). This enables easier investigation of perturbations to optics of say ring coolers by the introduction of injection/extraction systems.
- Geant does not have electric fields. We have changed the Runge-Kutta routine in Geant to use electric fields correctly. Integration of tof done correctly.

Geant3 modified

- Electric fields added
- dE/dx, multiple scattering done well in Geant3
- Electromagnetic showers and hadronic interactions done well
- Arbitrarily complex geometry shapes available by nesting Geant3 shapes
- One can feed in 3D magnetic fields that are realistic.
- We hope to study the problem of injection/extraction into ring coolers using these tools.

Equations of motion in presence of electric and magnetic fields

$\vec{p}$, E is the particle 4 vector, $\vec{u}$ is the tangent to the trajectory, s the arc length, v the velocity, η is the Lorentz factor
c the velocity of light,
m_0 the particle mass, q the charge
$\vec{\varepsilon}$ is the electric field, $\vec{B}$ is the magnetic field

$$\frac{d\vec{p}}{dt} = q(\vec{\varepsilon} + \vec{v} \times \vec{B})$$

$$\frac{d\vec{p}}{dt} = \frac{d\vec{p}}{ds} \times \frac{ds}{dt} = v\frac{d\vec{p}}{ds}$$

$$\vec{p} = \vec{u}\, m_0 c\, \eta$$

$$p\frac{dp}{ds} = \vec{p} \circ \frac{d\vec{p}}{ds} \Rightarrow \frac{dE}{ds} = q(\vec{\varepsilon} \circ \vec{u}) \quad (1)$$

$$\frac{d\vec{u}}{ds} = \frac{d^2\vec{x}}{ds^2} = \frac{q}{p}\left(\vec{u} \times \vec{B} + \frac{\vec{\varepsilon}}{v} - \frac{\vec{\varepsilon} \circ \vec{u}}{v}\vec{u}\right) \quad (2)$$

$$\frac{dt}{ds} = \frac{1}{v} \quad (3)$$

Runge-Kutta Equations

Runge-Kutta is performed on 3 equations simultaneously.Nystrom algorithm

$$y'' = f(y', y, x)$$

solves to

$$y(x+h) = y(x) + hy'(x) + (h^2/6)(K_1 + K_2 + K_3) + O(h^5)$$

$$y'(x+h) = y'(x) + (h/6)(K_1 + 2K_2 + 2K_3 + K_4) + O(h^5)$$

$$K_j = f(y'_j, y_j, x_j) \text{ for } j = 1,2,3,4$$

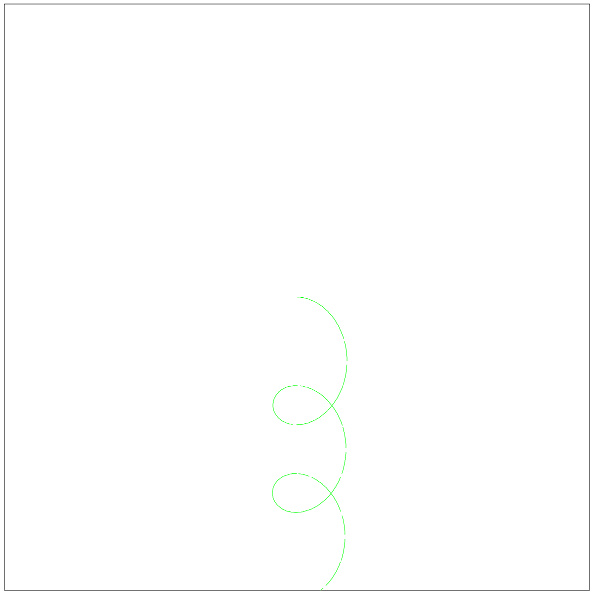
$$x_1 = x, x_2 = x_3 = x + h/2, x_4 = x + h$$

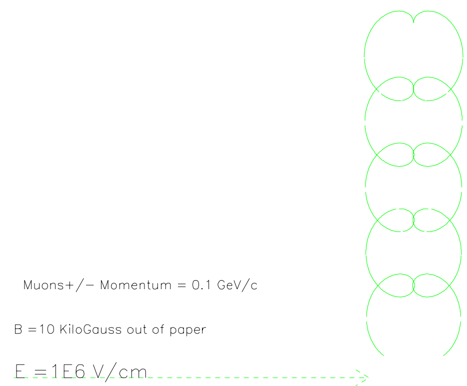
$$y_1 = y(x), y_2 = y_3 = y(x) + (h/2)y'(x) + (h^2/8)K_1$$

$$y_4 = y(x) + hy'(x) + (h^2/2)K_3$$

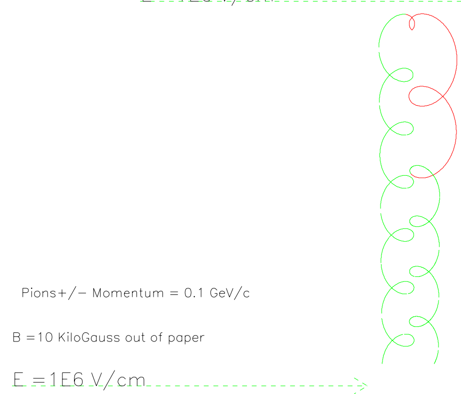
$$y'_1 = y'(x), y'_2 = y'(x) + (h/2)K_1, y'_3 = y'(x) + (h/2)K_2,$$

$$y'_4 = y'(x) + hK_3$$

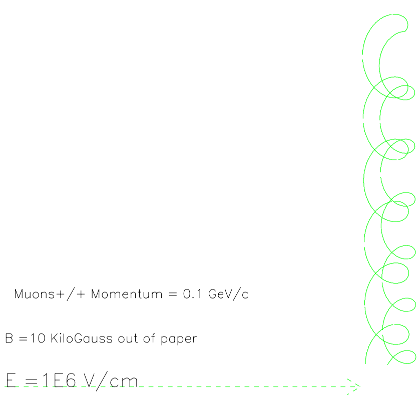




Muons+/− Momentum = 0.1 GeV/c
B =10 KiloGauss out of paper
E =1E6 V/cm

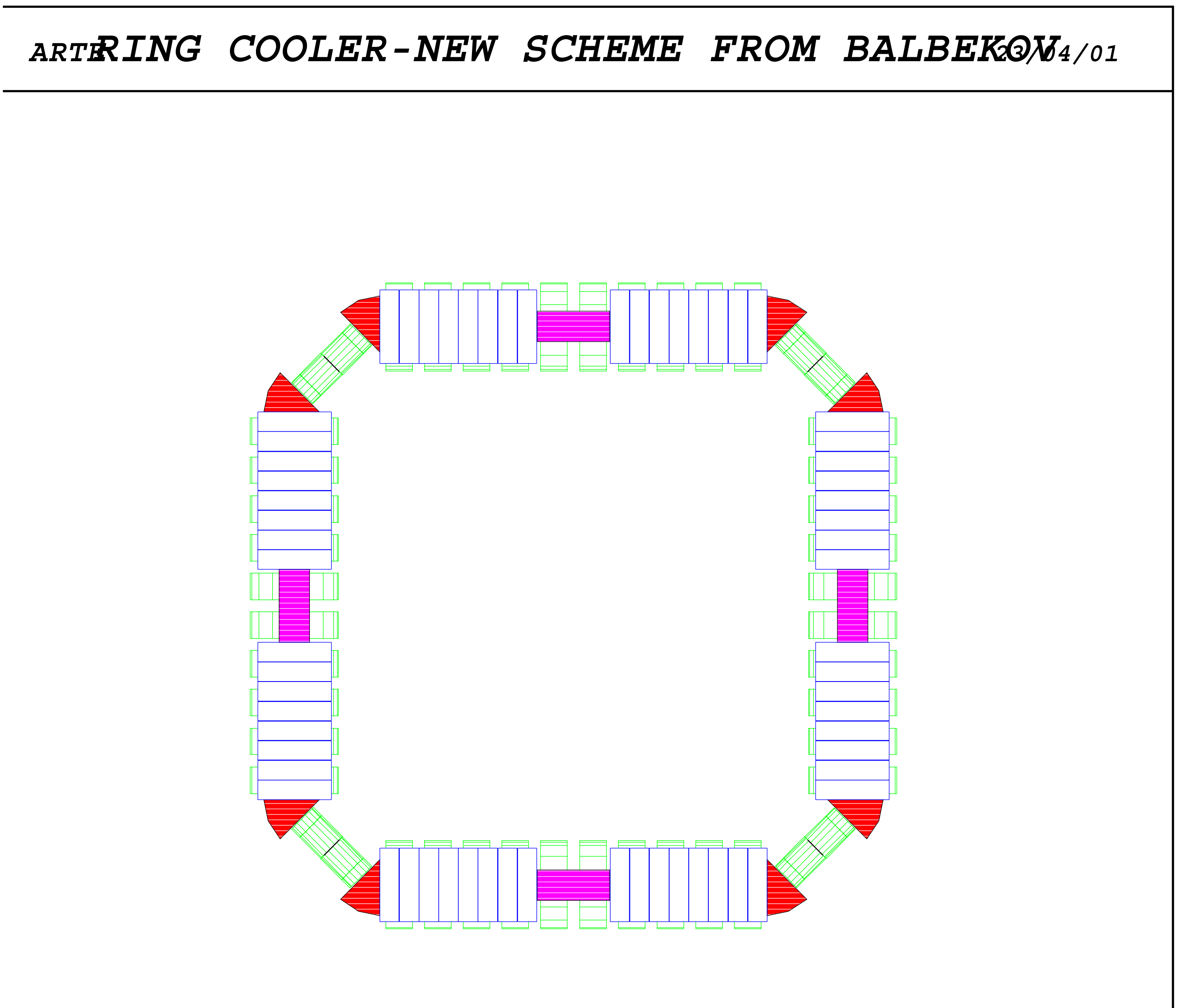


Pions+/− Momentum = 0.1 GeV/c
B =10 KiloGauss out of paper
E =1E6 V/cm

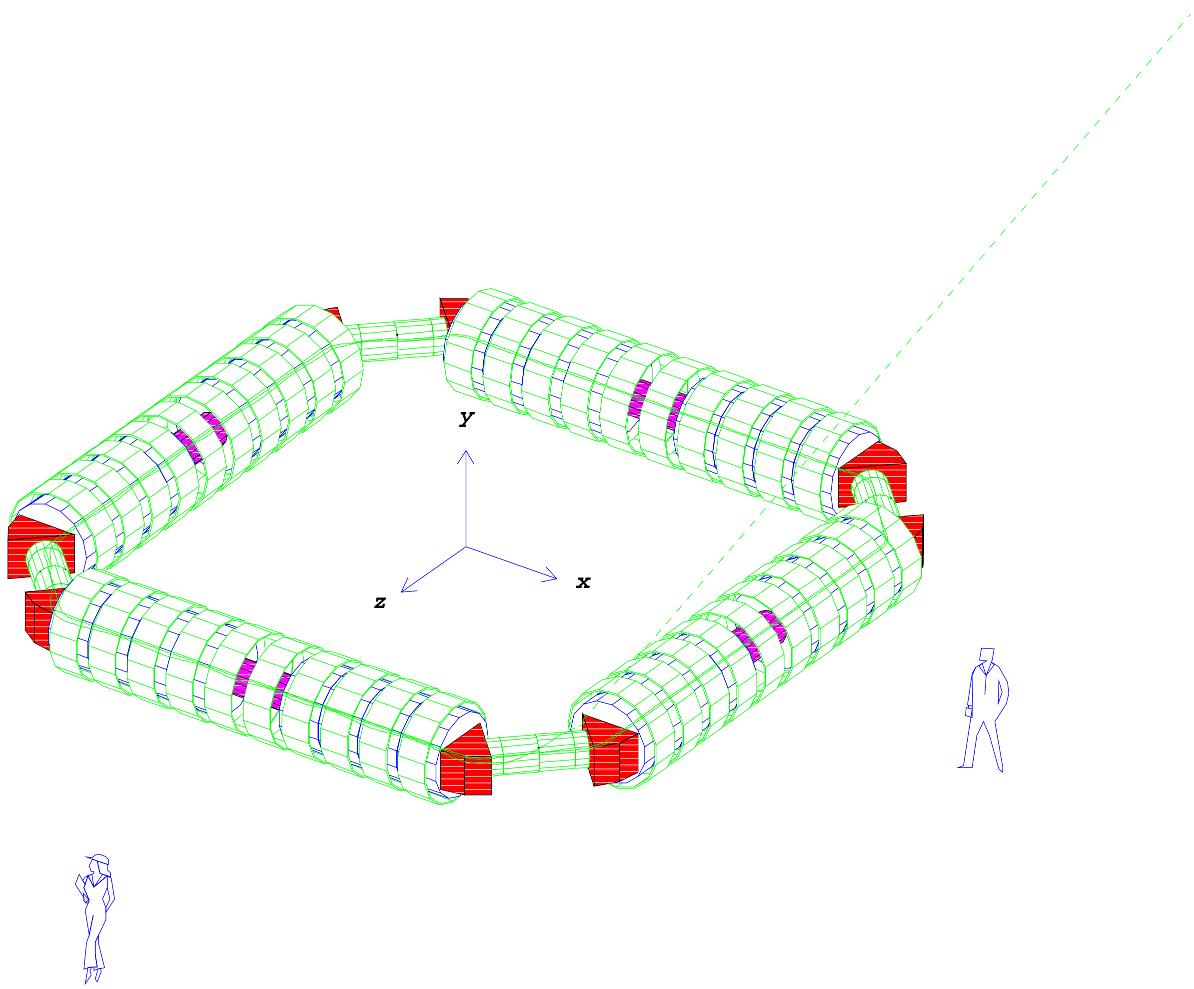


Muons+/+ Momentum = 0.1 GeV/c
B =10 KiloGauss out of paper
E =1E6 V/cm

Geant Simulation of ring cooler



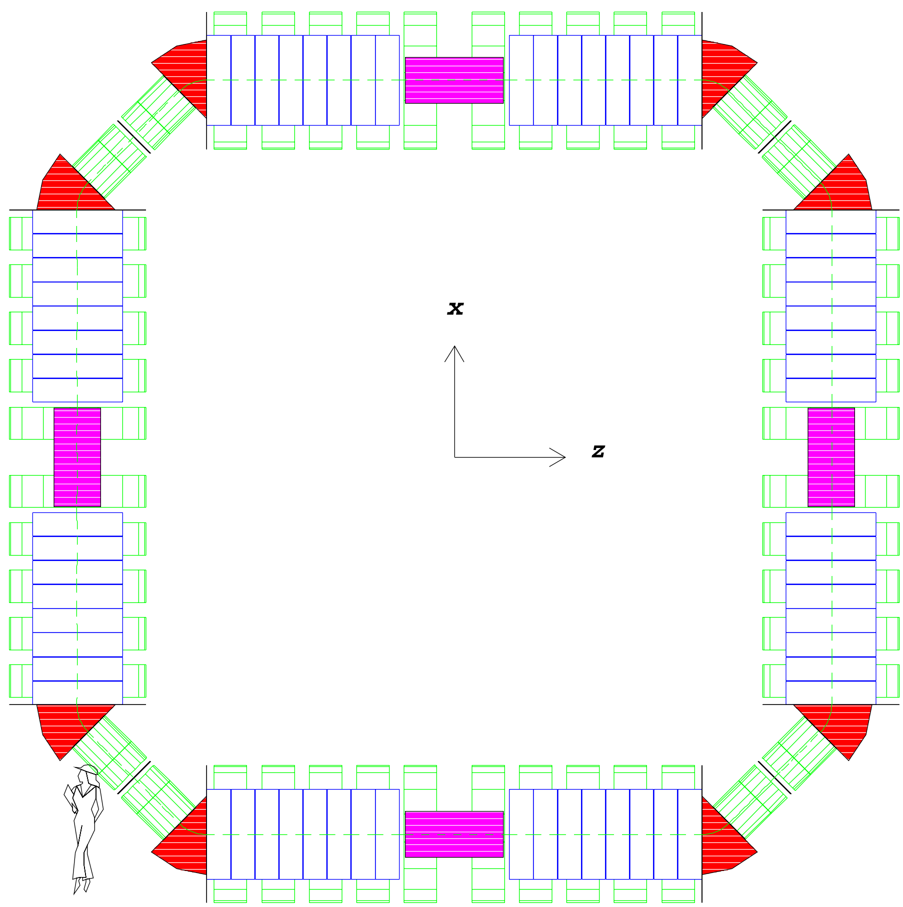
Geant Simulation of ring cooler

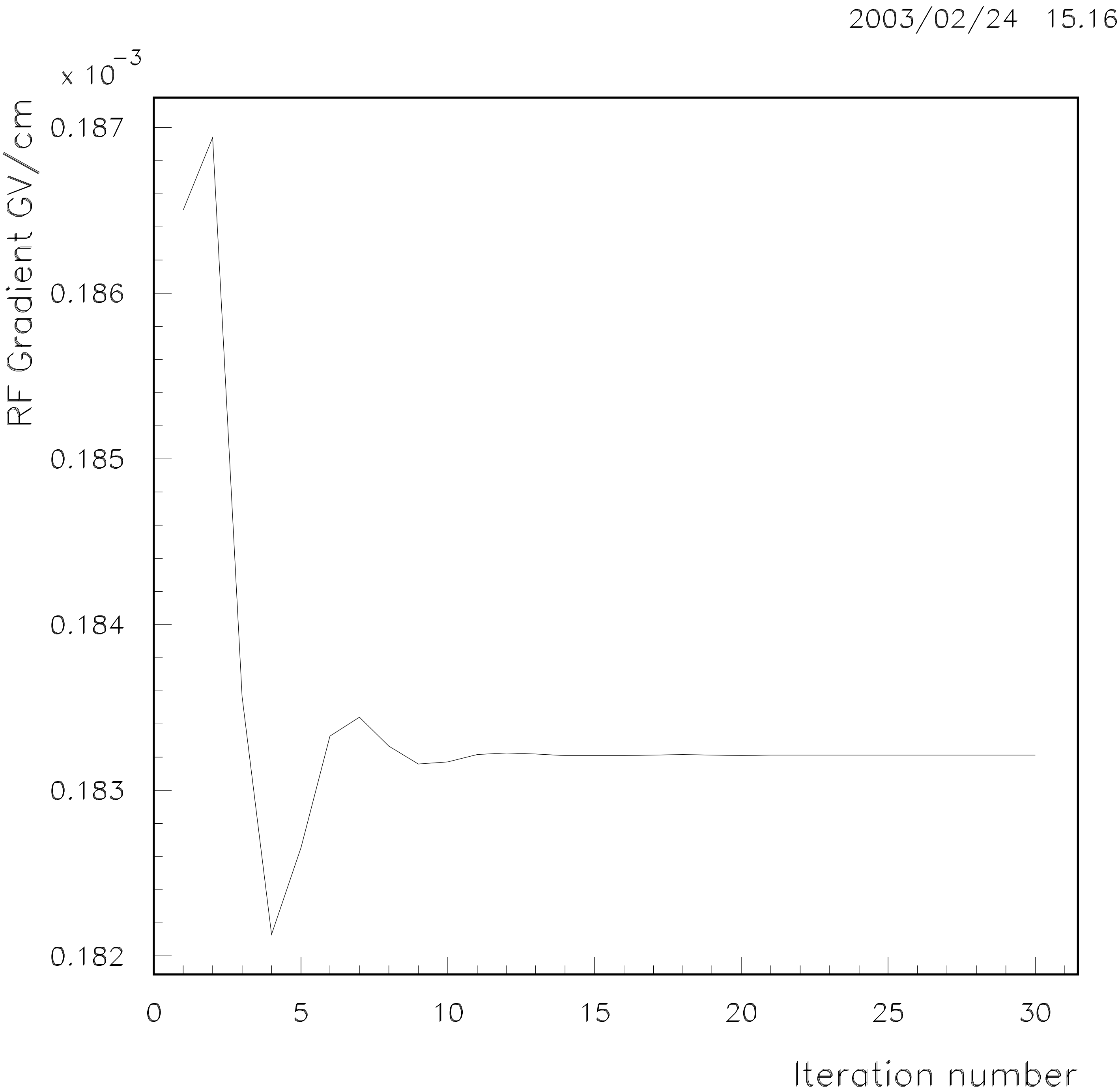


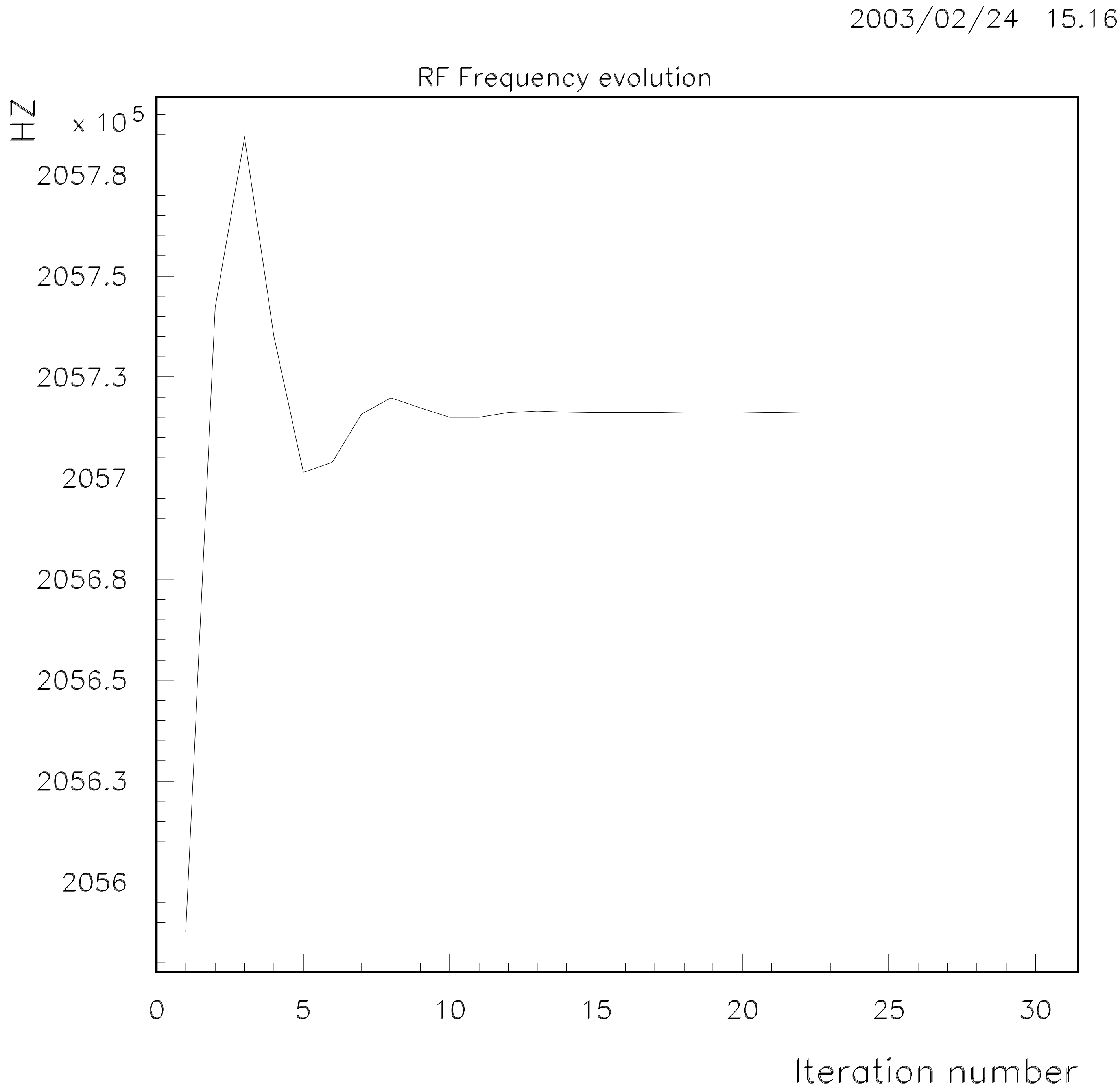
MITER

- Separate program that calls Geant.
- Has interface to MINUIT
- Present algorithm
- Remove all absorbers.
- Acquire times at which on momentum particle crosses all rf volumes (16x4)
- Start particle at beginning of quadrant and track one turn
- Work out rf frequency for a harmonic number =28
- Replace main absorbers. No wedges.
- Iterate One Turn with no straggling or multiple scattering or decay.
- Re-work out the times.
- Re calculate RF gradient such that loss per absorber = gain / quadrant.
- Re work out the rf frequency. Iterate 30 times till convergence.
- RF entry at –15 degrees and exit at ~ 75degrees. Sin Wave.

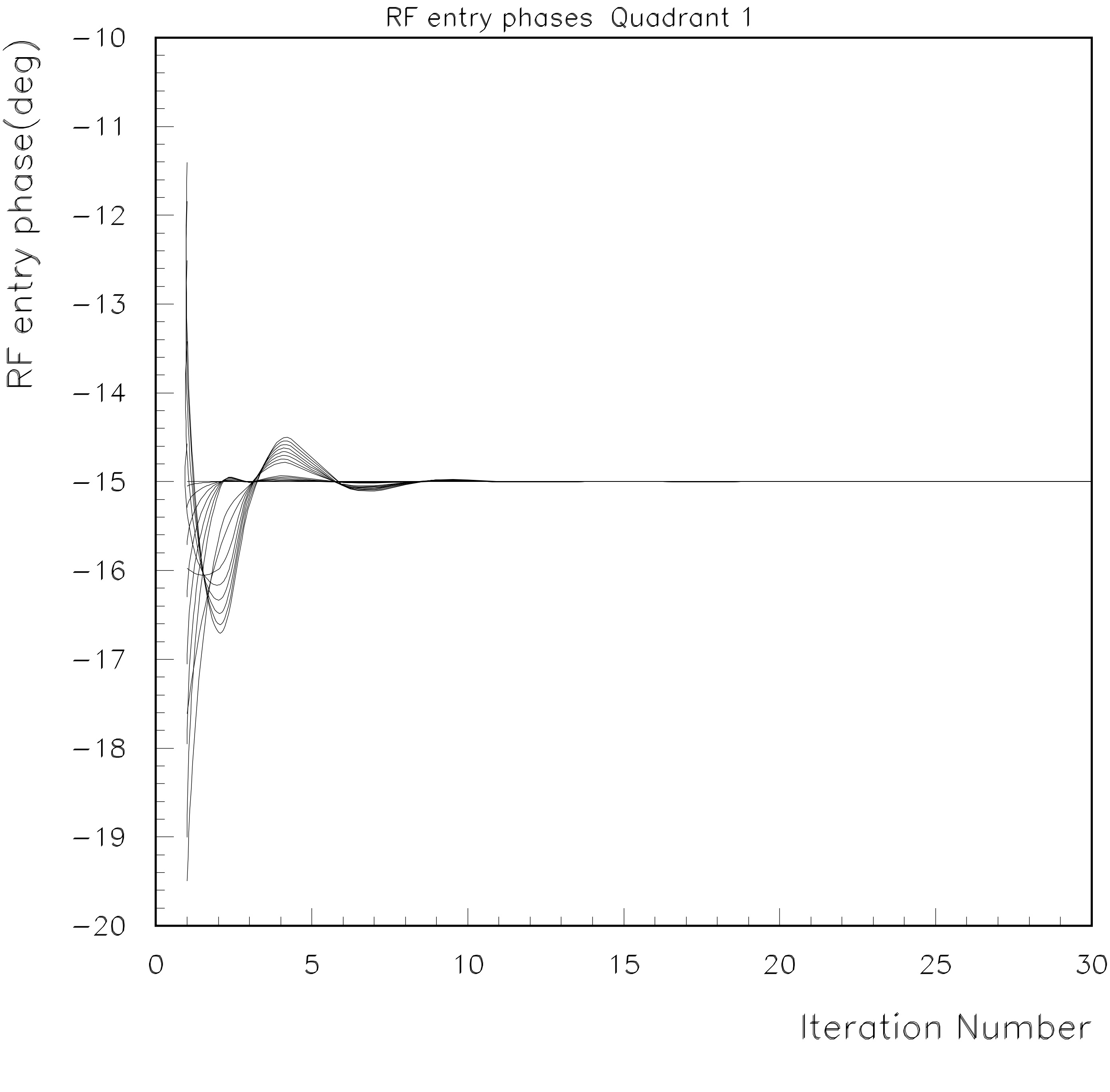
ARTE RING COOLER-NEW SCHEME FROM BALBEKOV 24/02/03




2003/02/24 15.16
x 10^-3
RF Gradient GV/cm
0.187
0.186
0.185
0.184
0.183
0.182
0
5
10
15
20
25
30
Iteration number


2003/02/24 15.16
RF Frequency evolution
HZ
x 10^5
2057.8
2057.5
2057.3
2057
2056.8
2056.5
2056.3
2056
0
5
10
15
20
25
30
Iteration number

2003/02/24 15.16



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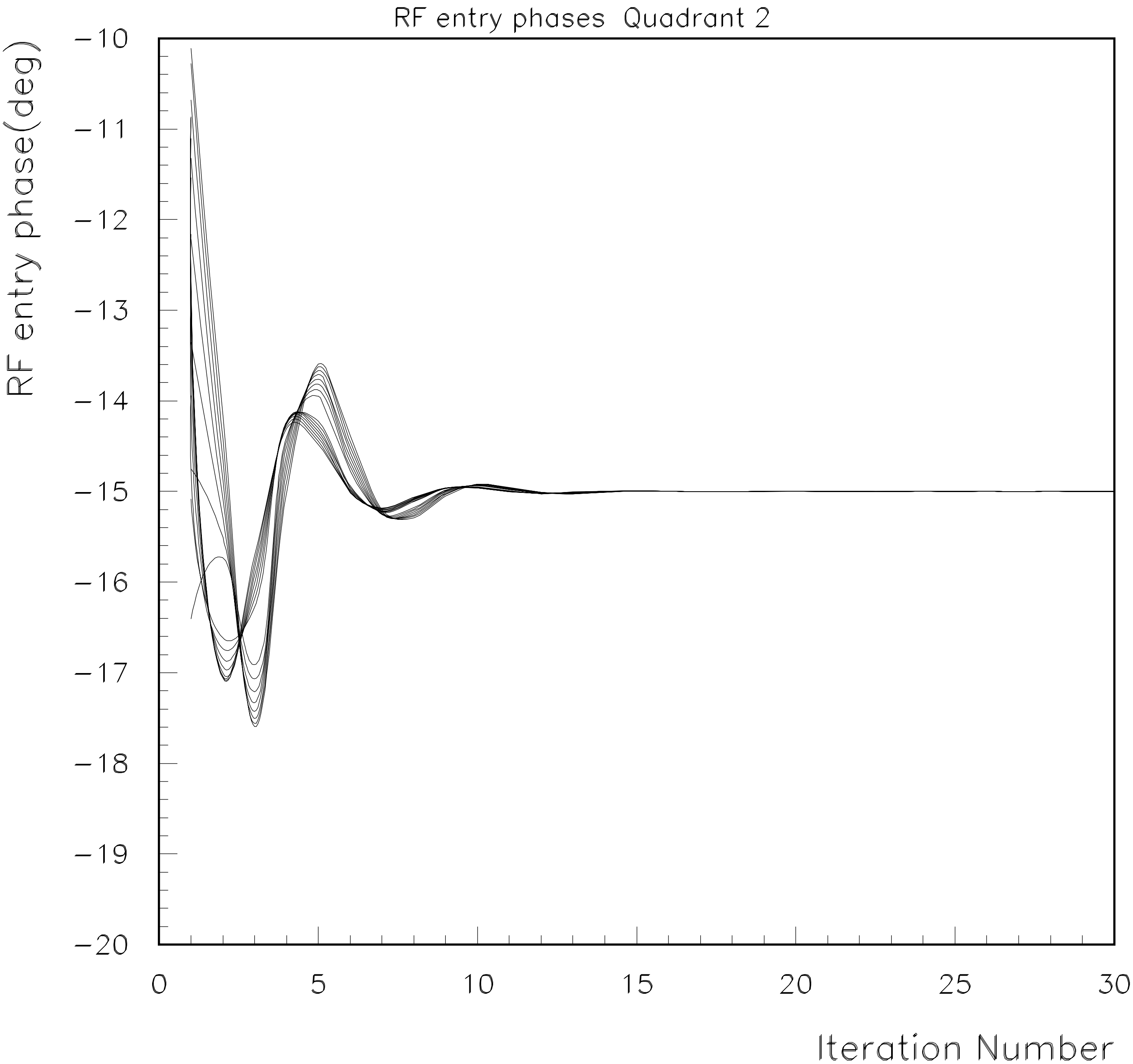

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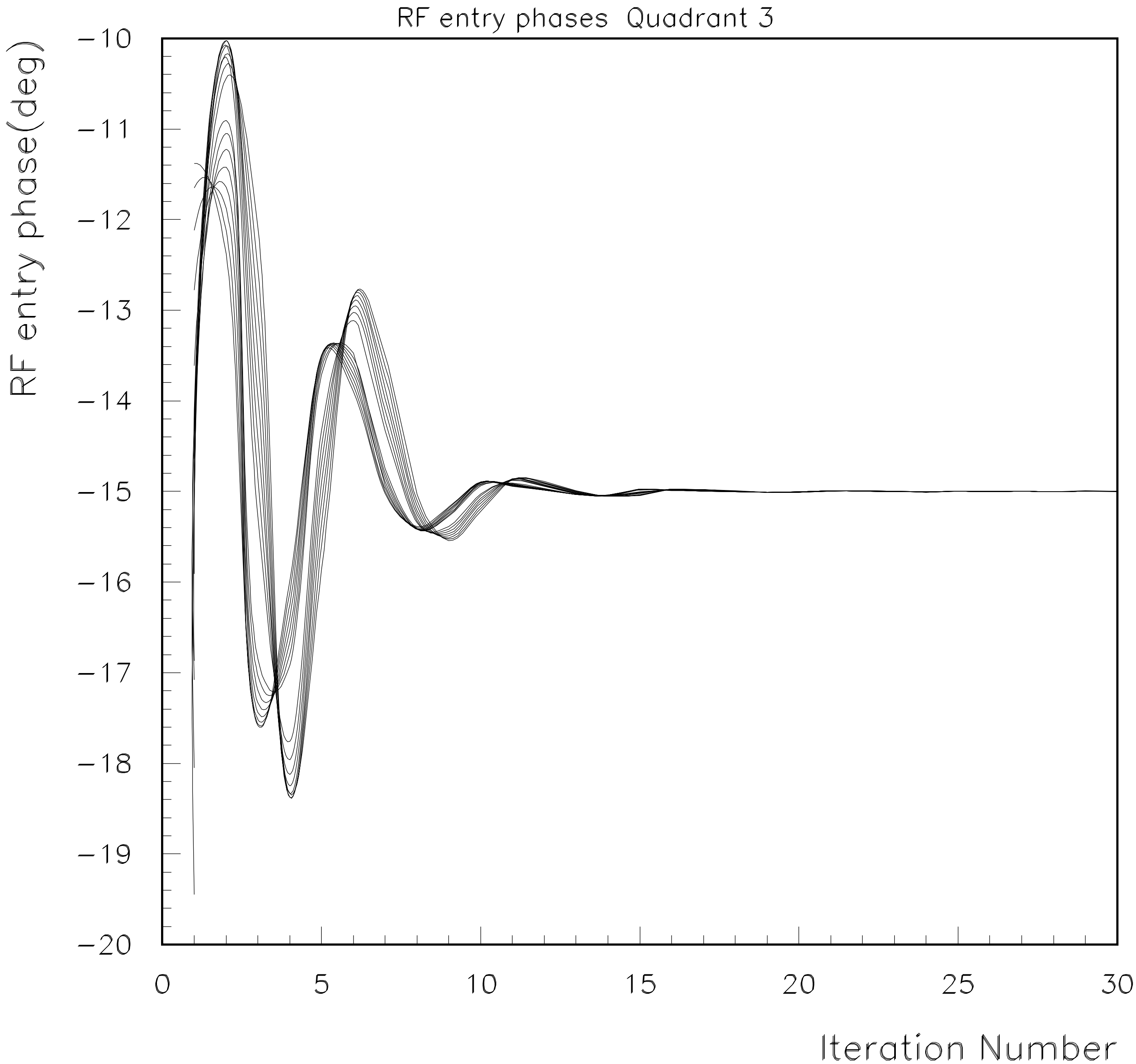
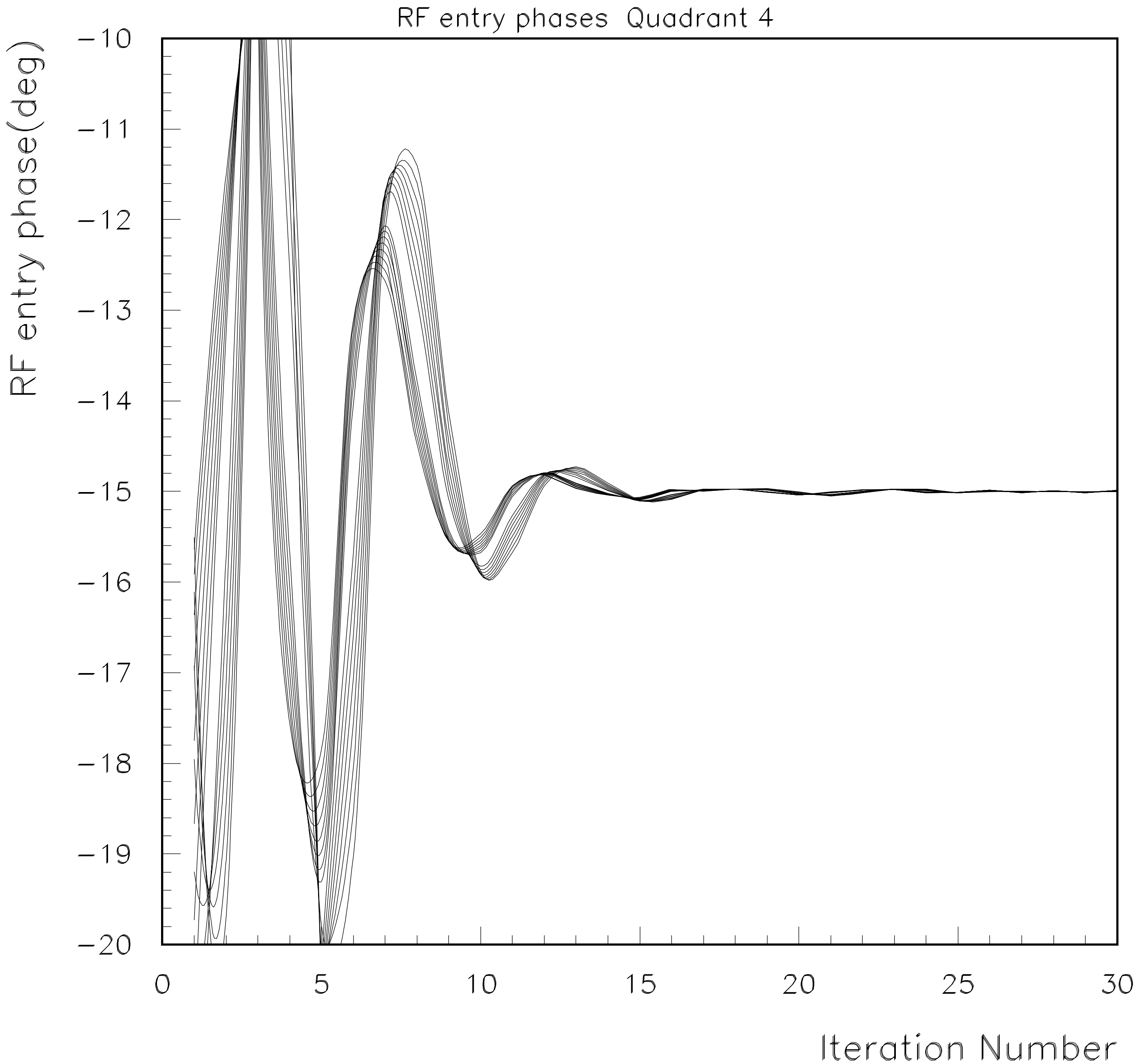
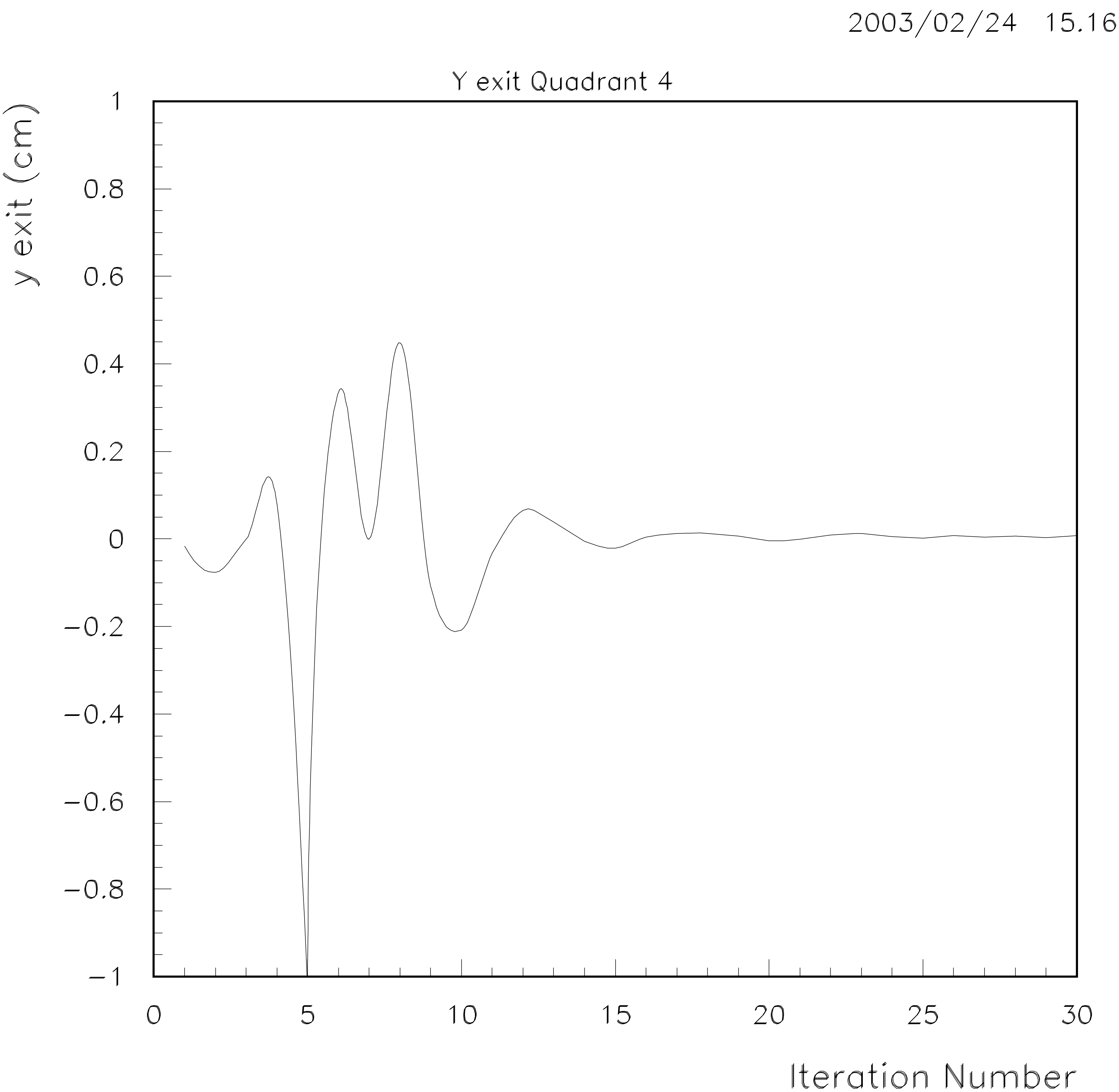
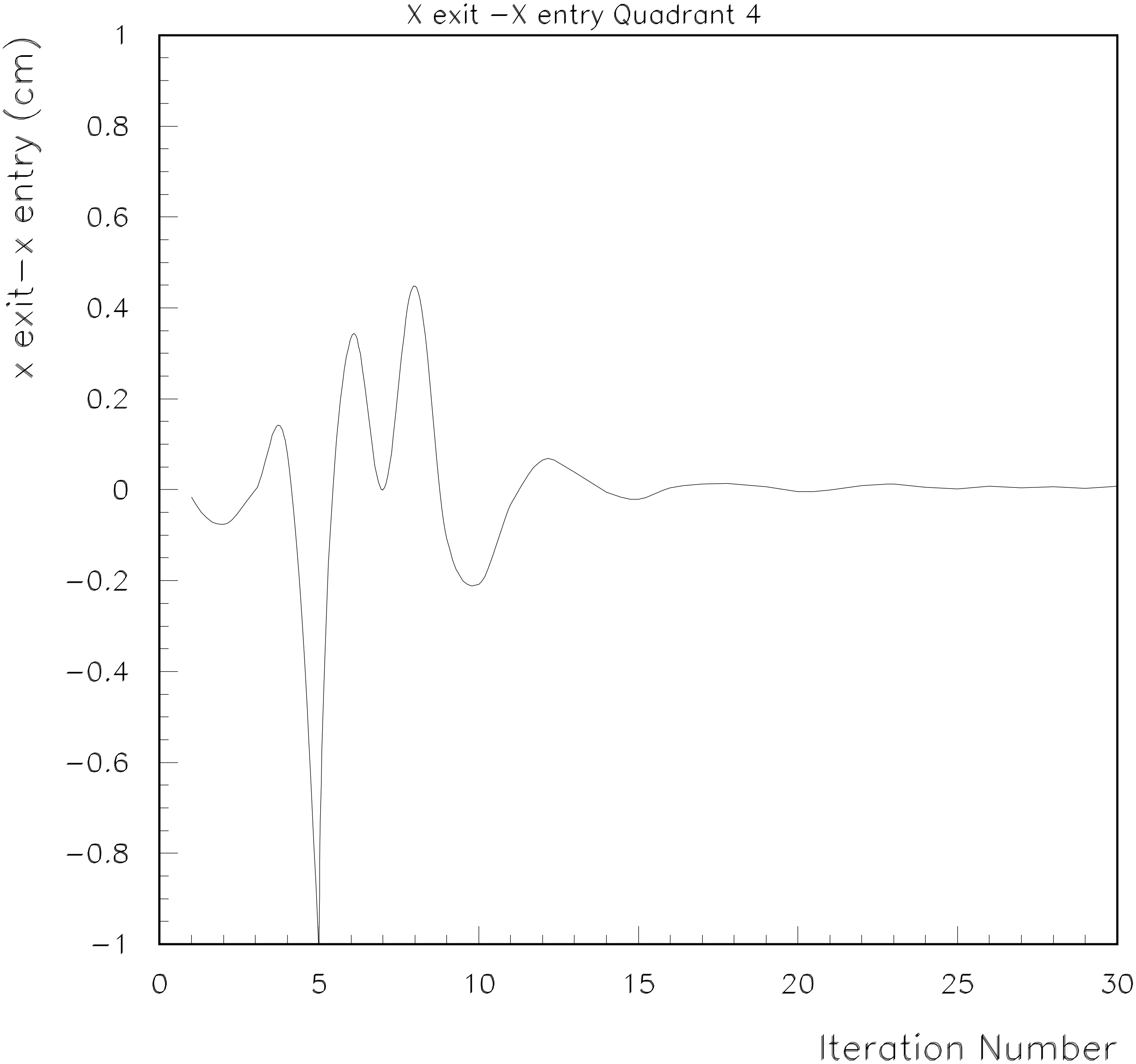


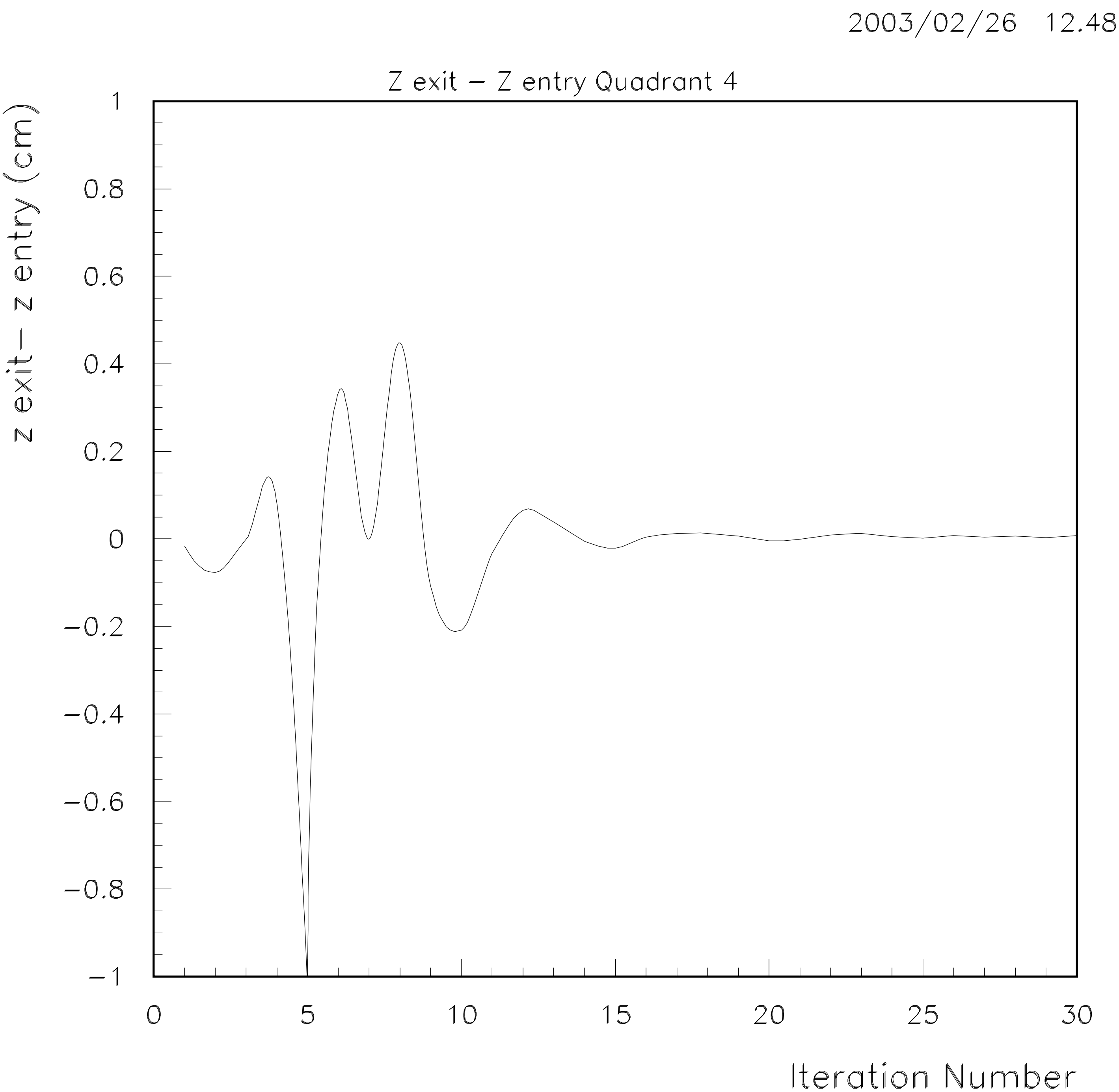
2003/02/24 15.16




2003/02/24 15.16
Y exit Quadrant 4
y exit (cm)
1
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
−1
0
5
10
15
20
25
30
Iteration Number

2003/02/26 12.48



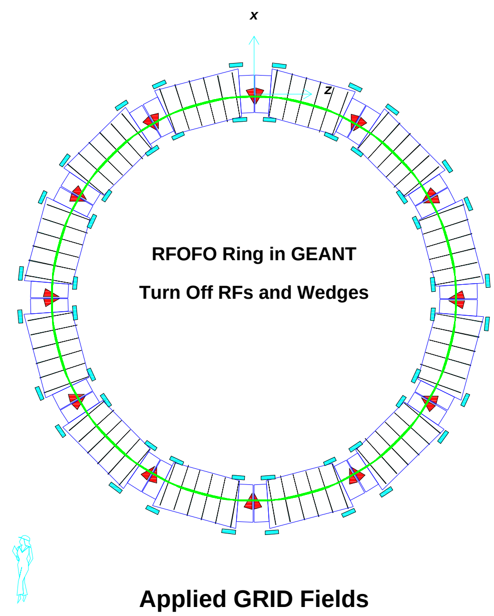

2003/02/26 12.48
Z exit − Z entry Quadrant 4
z exit− z entry (cm)
1
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
−1
0
5
10
15
20
25
30
Iteration Number

RFOFO in GEANT Update...

- The By fields discrepancy generated by BSHEET and Biot-Savart are consistent!
- We generated 1cm x 1cm x 1cm GRID fields map with tilt angle of 53 mradians
- The fundamental of Maxwell's equations $\Longrightarrow$ Div and Curl of B are very close to 0
- The CERN interpolation routine was used (FINT) and gave about 10^-4 T differences compared to the real fields

GEANT Turns Particle...

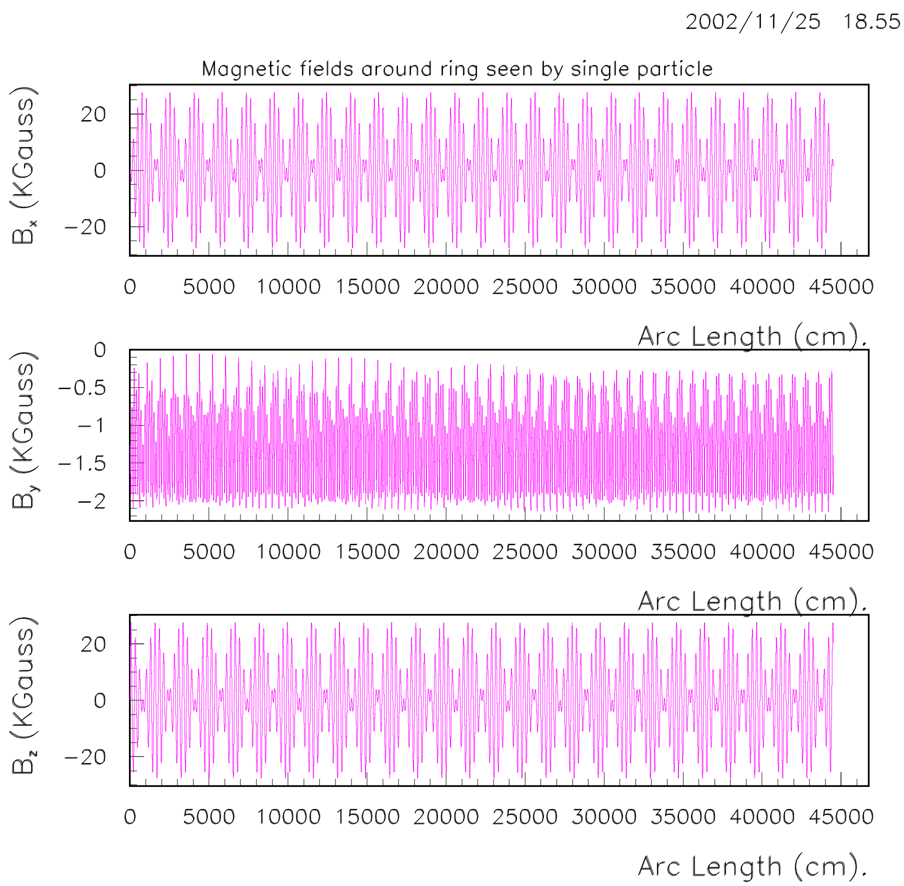
- Turn off RFs and Wedges and applied fields
  GEANT turns particle in RFOFO



- **Particle can go around forever...**

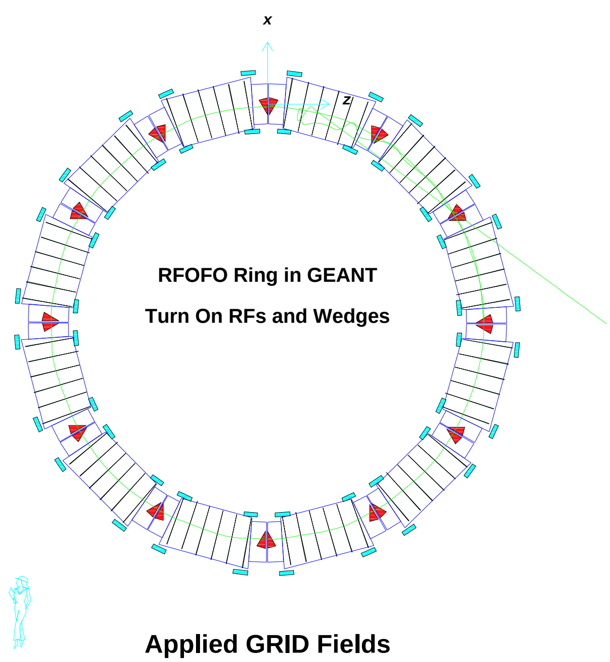
Fields Seen by a Single Particle

- Particle goes around the RFOFO ring with many turns. The fields in Cartesian coordinates



Preliminary Study on Wedges and RF

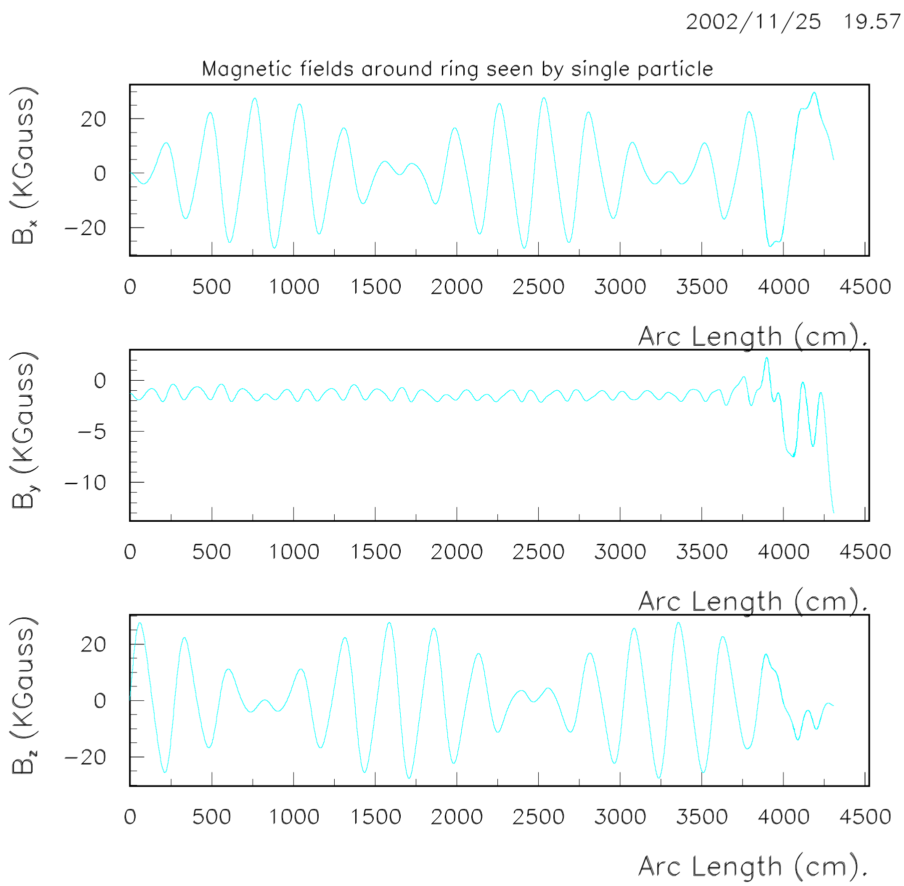
- We turn on RFs and wedges and study physics processes: energy loss and hadronic interaction



- We provide the fields in all cells...

Preliminary Study on Wedges and RF...

- **Fields seen by particle with energy loss and hadronic interaction**



Kirk-Garren Dipole Ring

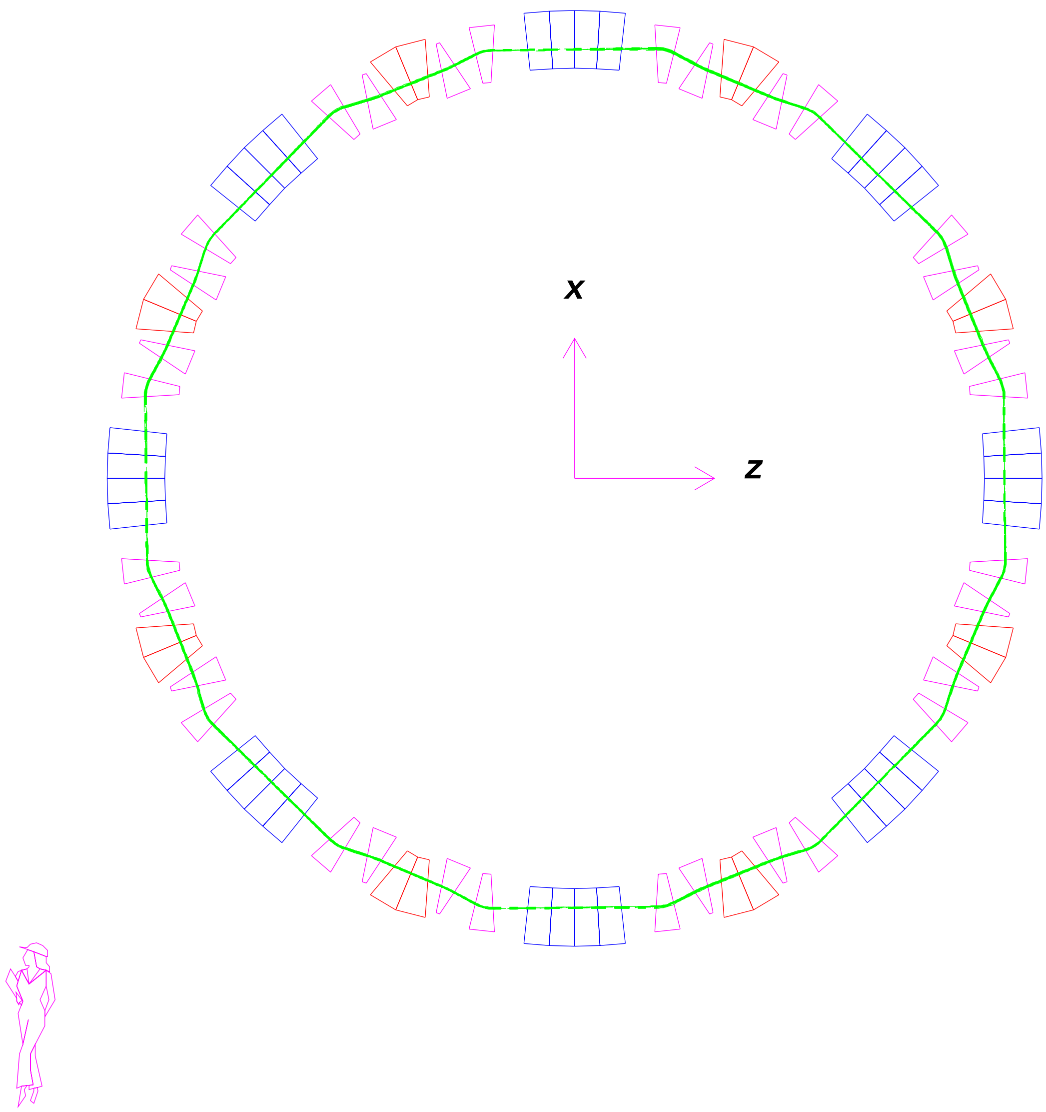


Figure 1: Set-up of Kirk-Garren Dipole Ring.

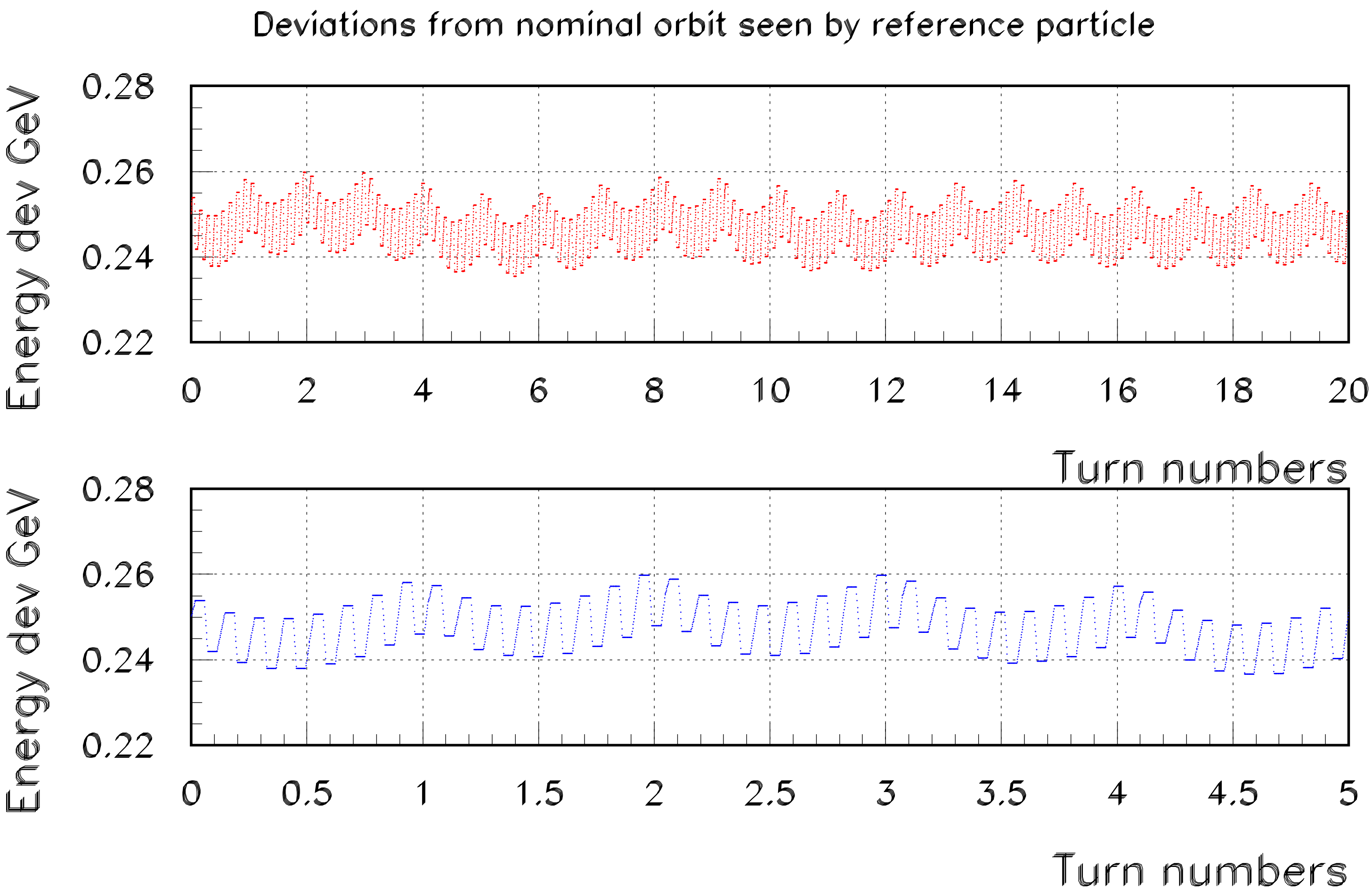


Figure 2: Energy deviation for reference paricle in Kirk-Garren Ring.

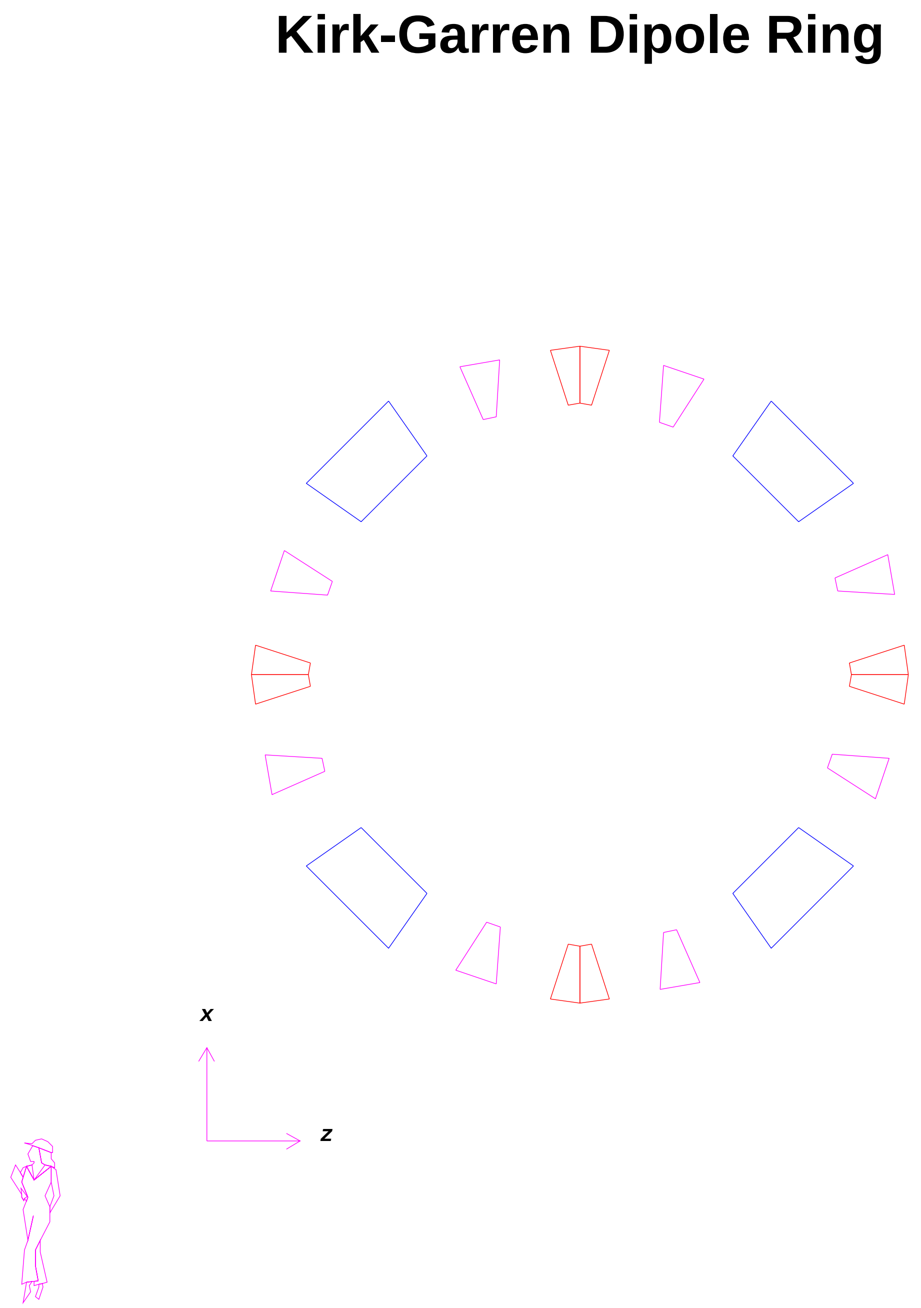
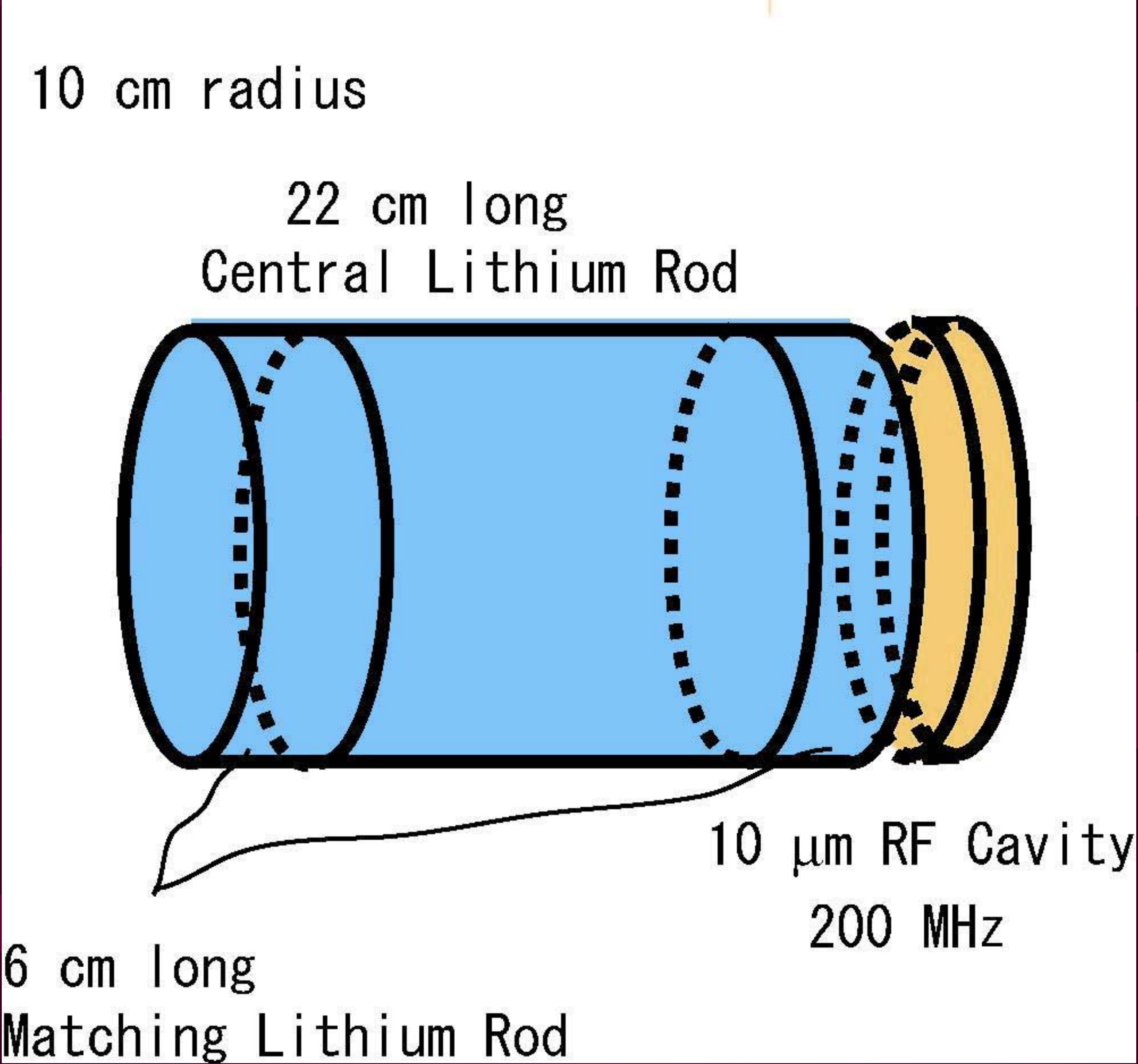
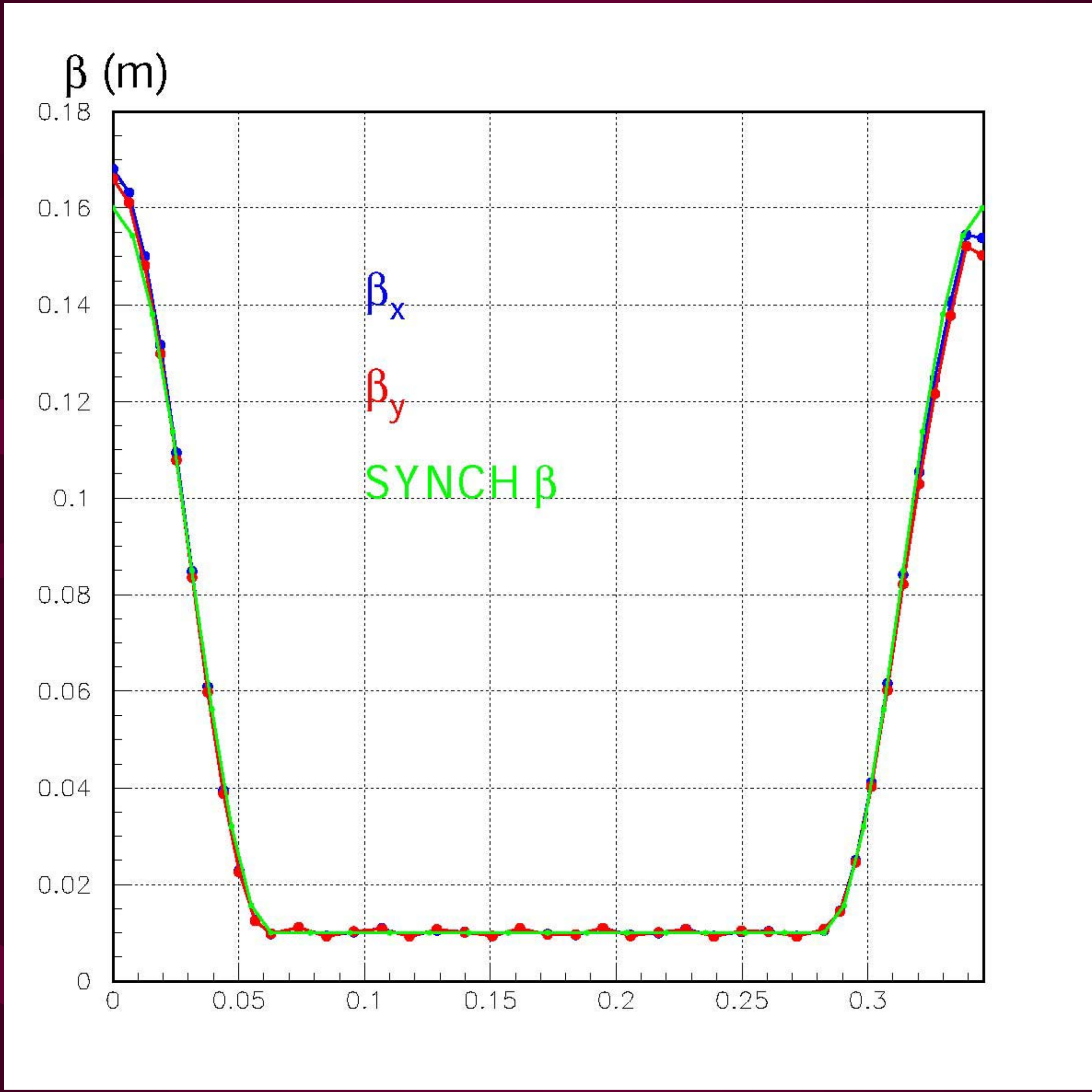


Figure 3: Set-up of New Kirk-Garren Dipole Ring.

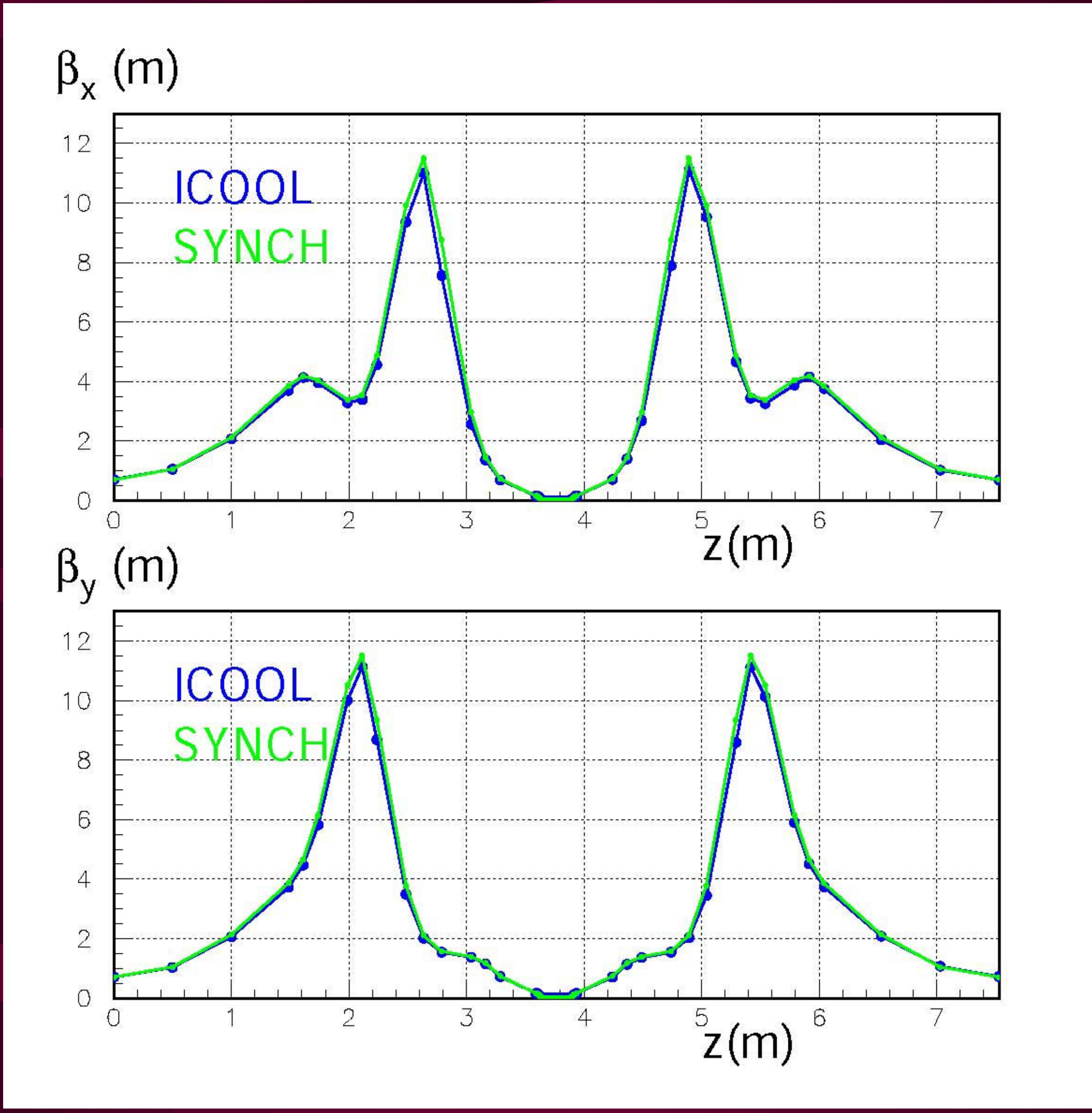
Li β=(4,1,4) cm



Li β=(4,1,4) cm

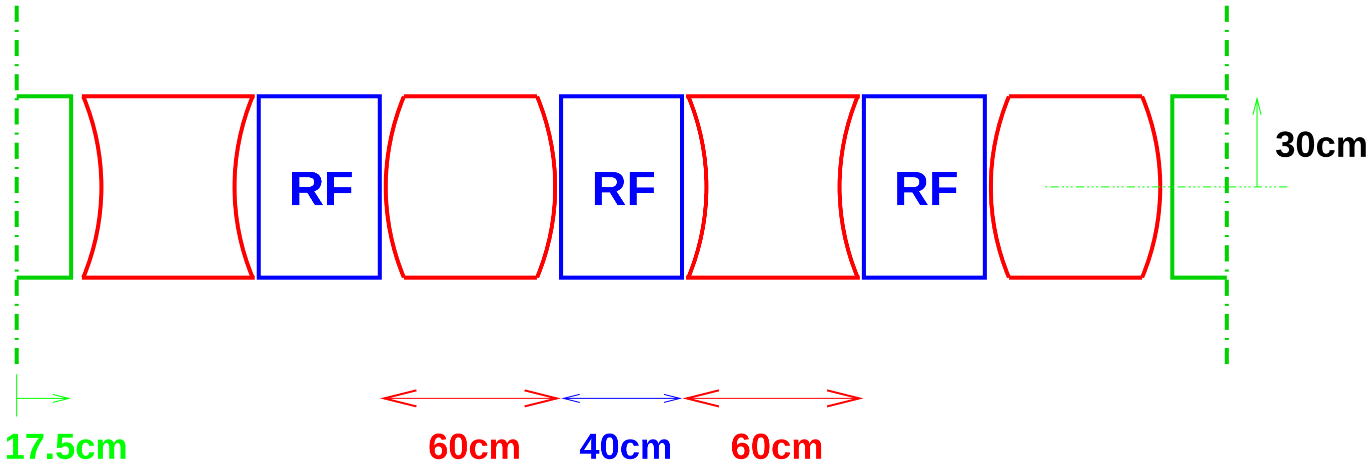

β (m)
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0.05
0.1
0.15
0.2
0.25
0.3
β_x
β_y
SYNCH β

Li β=(4,1,4) cm + Quad. Matching Cell



Quad Cooling Cell

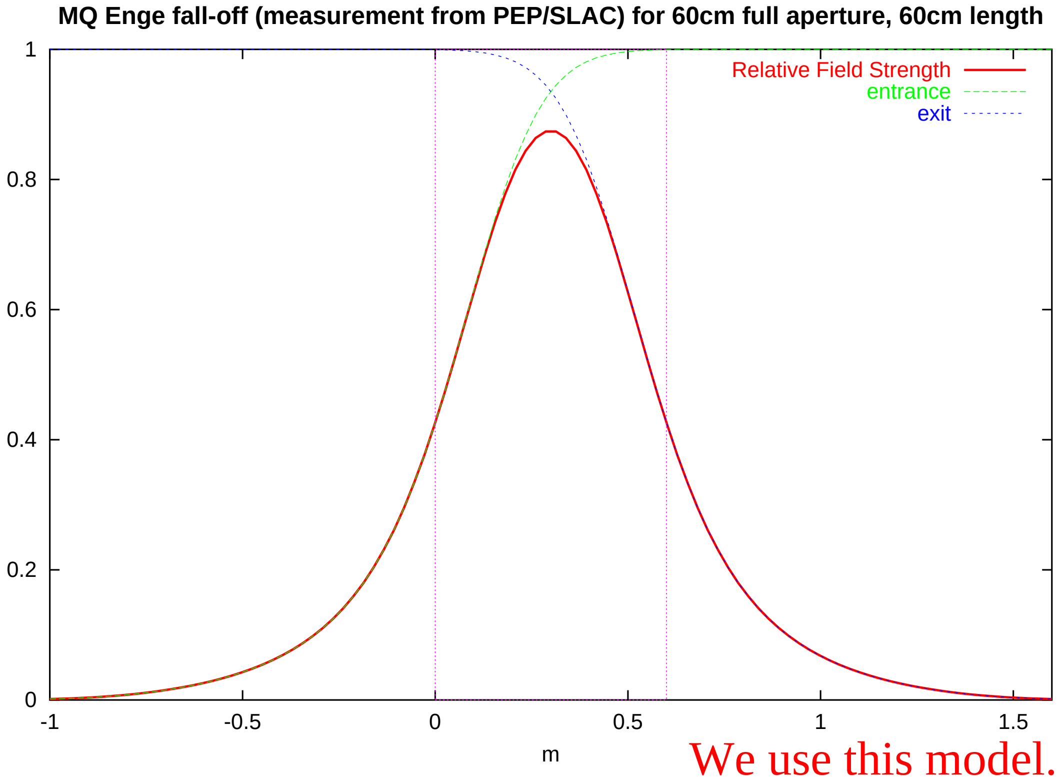
4m Cell



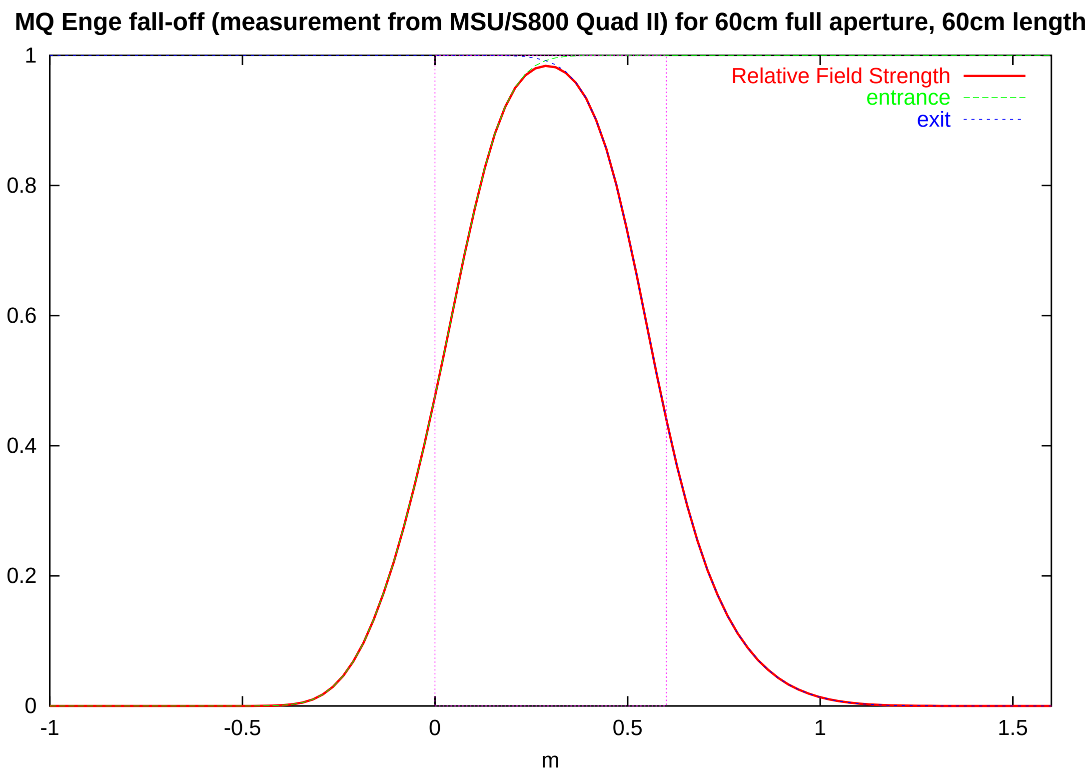
- Incoming Muons: 180 MeV/c to 245 MeV/c
- Magnetic Quadrupoles: k=2.88
- 35cm Liquid H Absorber: Energy loss ≈ 12 MeV.
  The same design as Study II 2.75m sFOFO cell.
- RF Cavity: Energy gain to compensate the loss.
  200 MHz, $\phi = 30°$.

Field Profile of Various Magnets

60cm full aperture, 60cm length Magnets

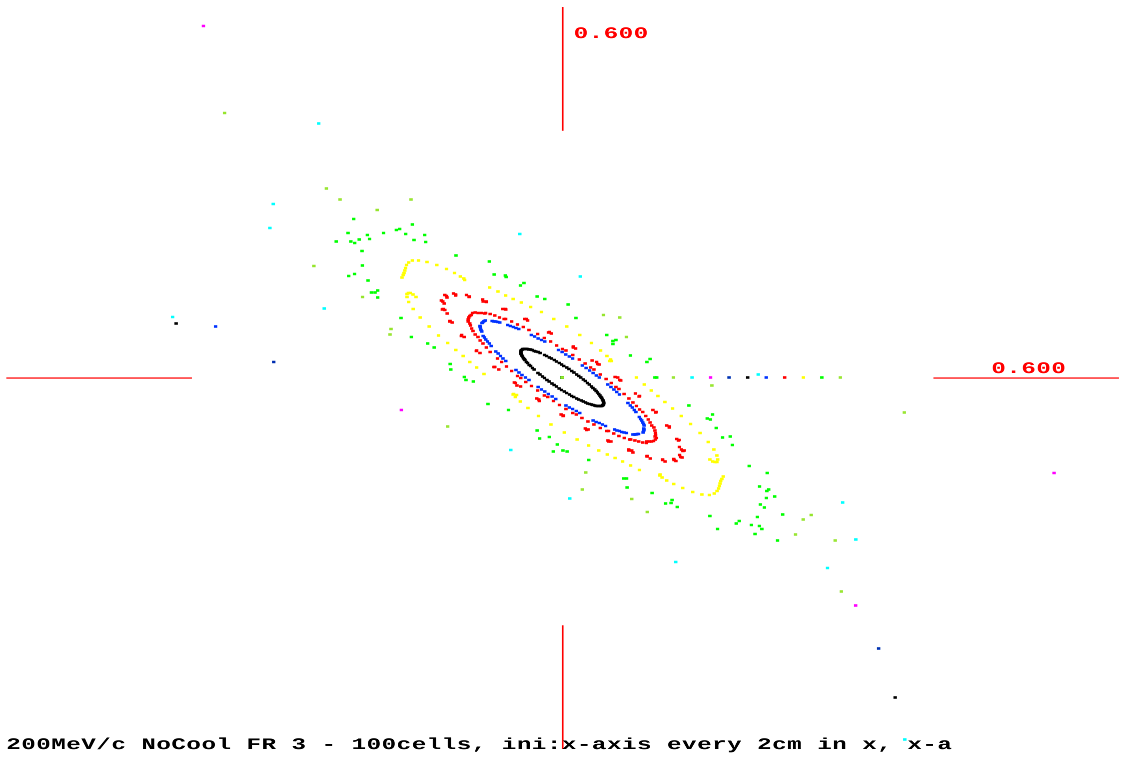


We use this model.

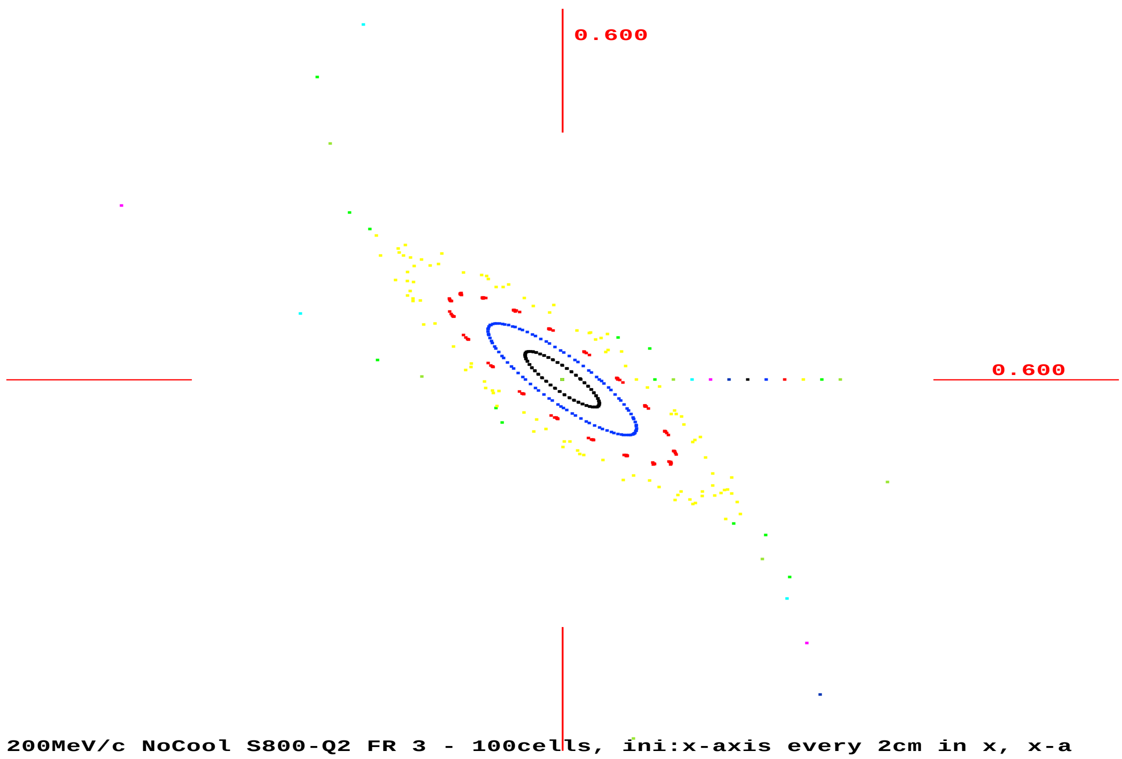


PEP/SLAC Quad Fringe Field Fall-off Model

⇒ We use this model at the moment.



S800 Q II Quad Fringe Field Fall-off Model



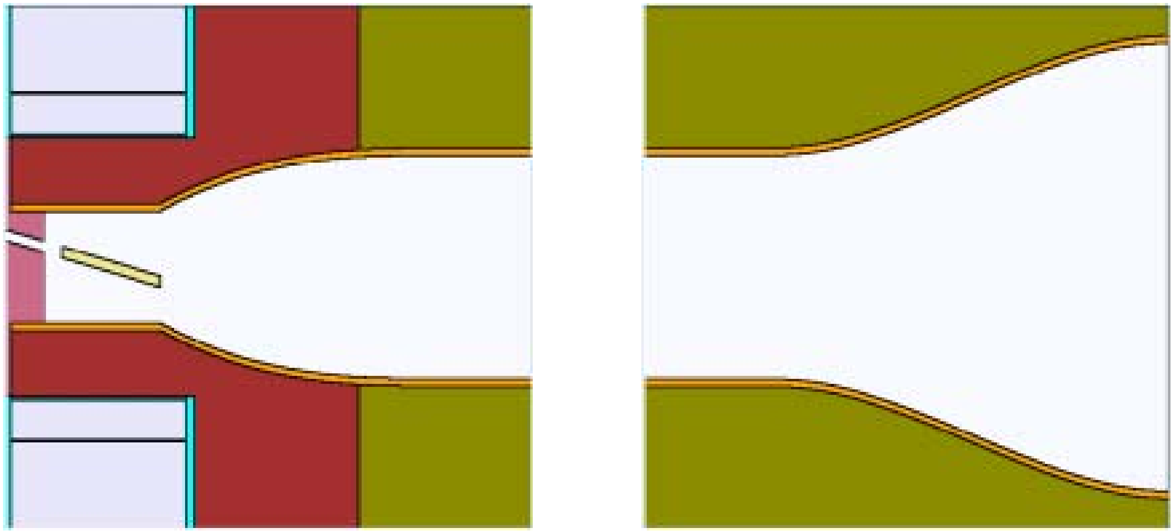
Pion/Muon Production using MARS

K. Paul

From work in collaboration with
C. Johnstone and **MARS** (i.e., Nikolia Mokhov)

- New horns...

...Before and after the 5 T decay channel:



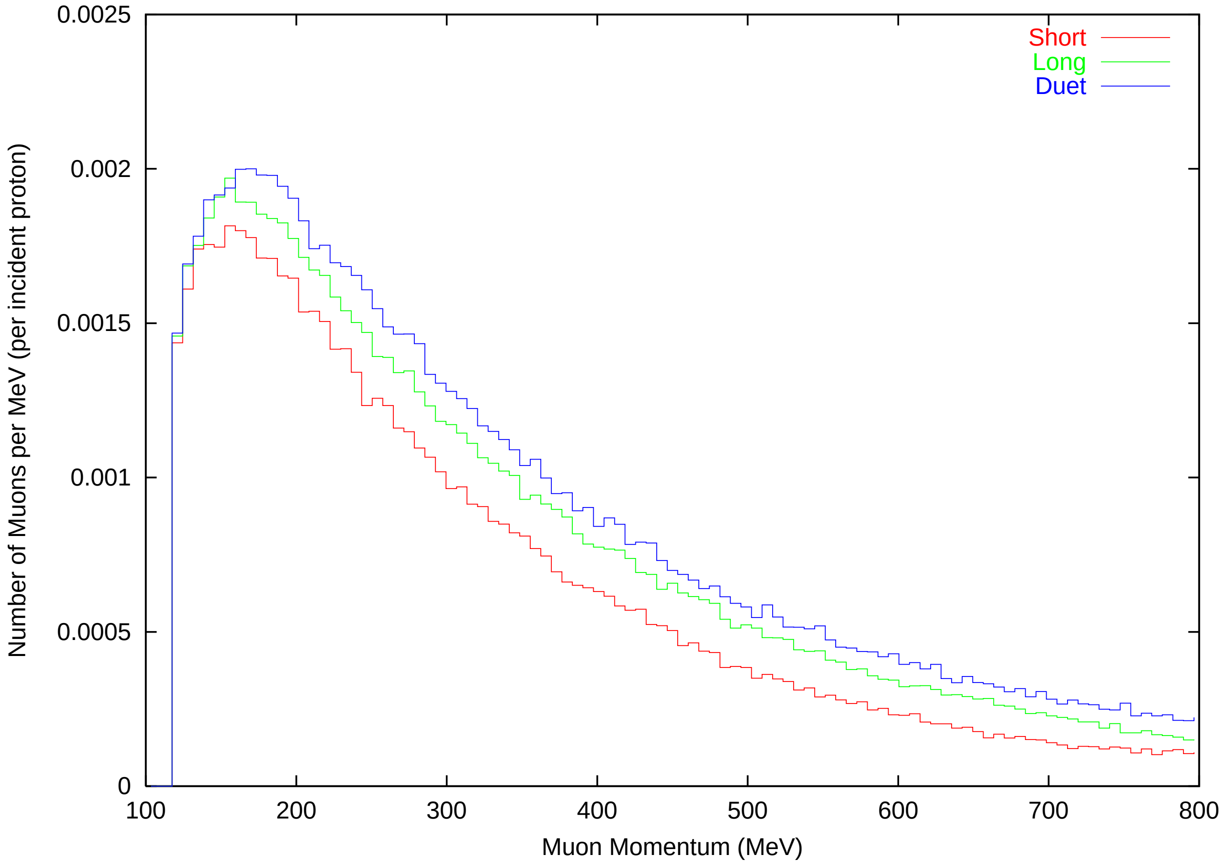
("ehem...Two Horns is a Duet!")

...Calculate muon yields:

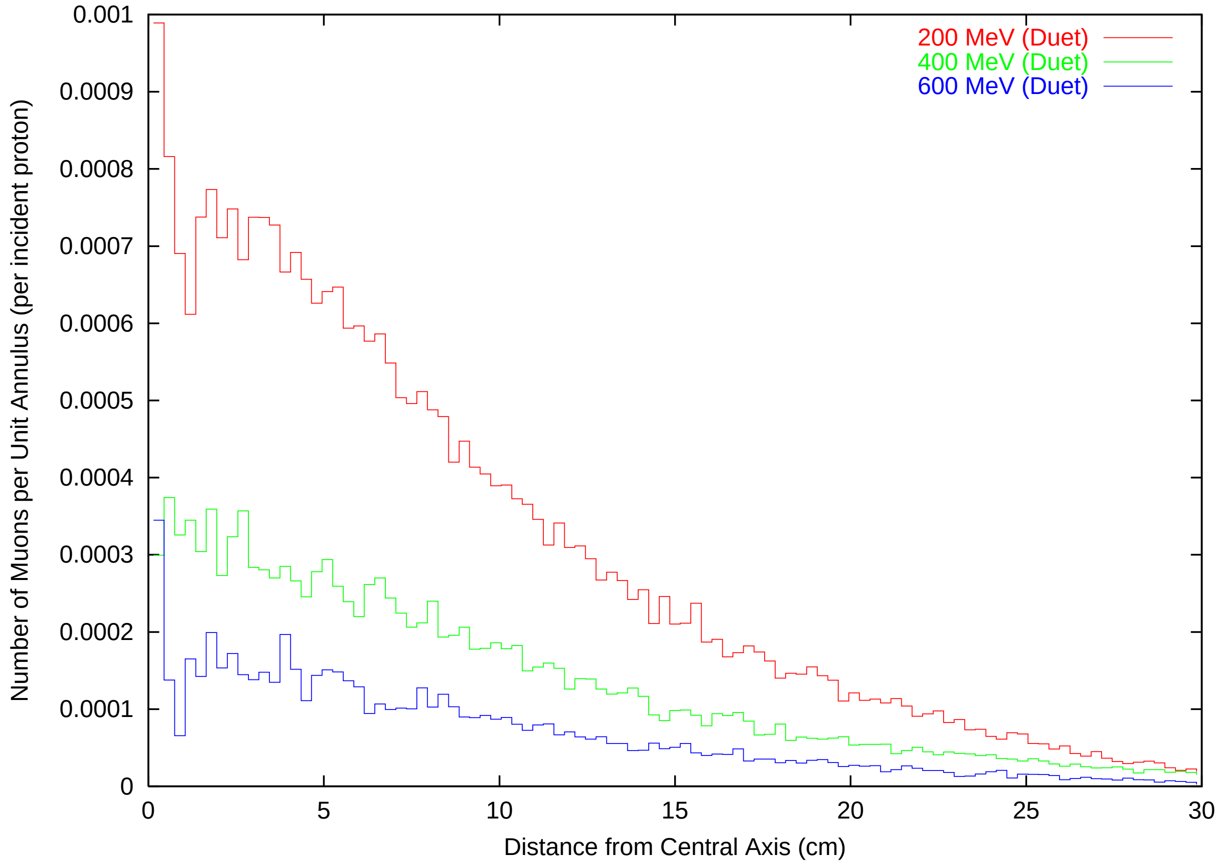
DUET: 0.192(+), 0.183(-) μ/P

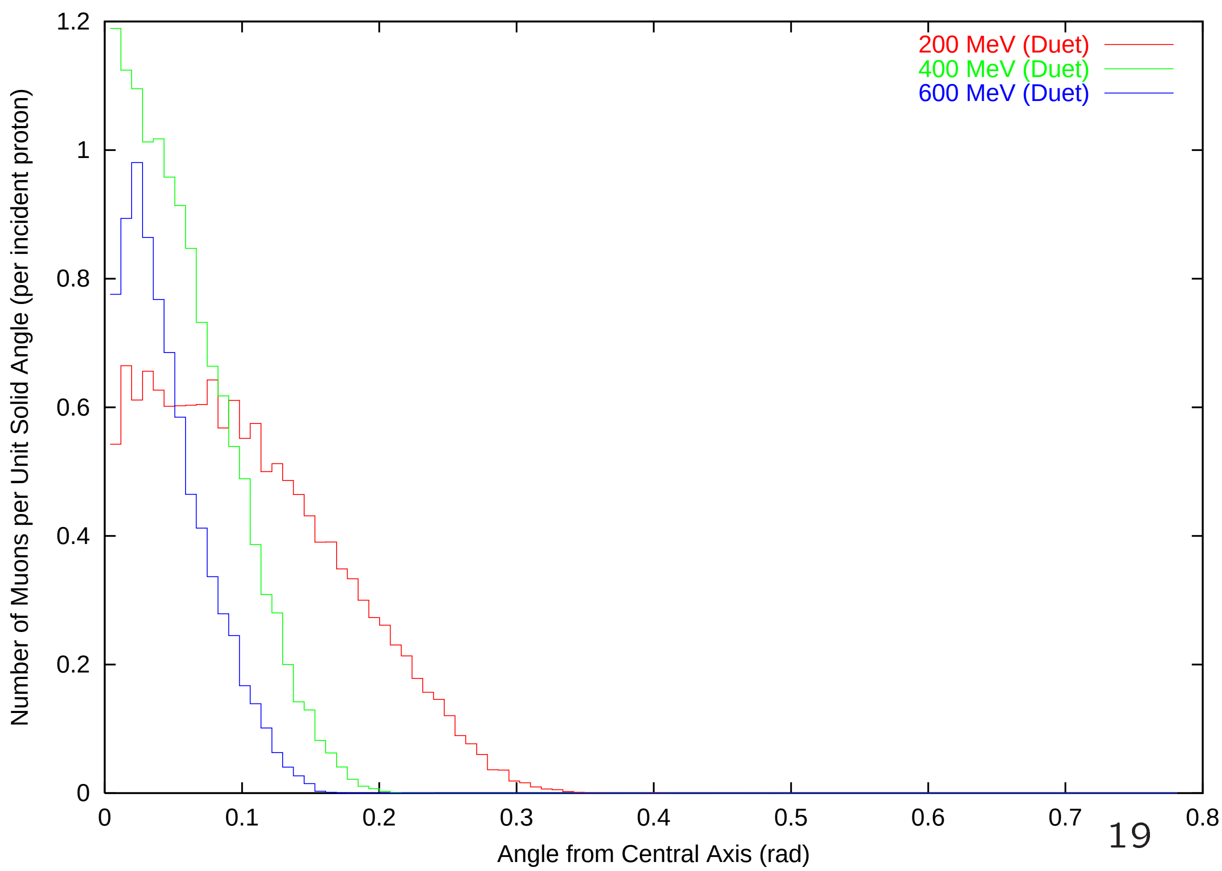
Approximately 15% improvement!

Duet momentum distribution:



Duet phase space distributions





- Things left undone...

  ...No energy deposition calculations

  ...Currently using Maxwellian but
  "unrealistic" magnetic fields

  ...Possibly shorter decay channel (cheaper)

  ...Longer horns in the duet configuration

  ..."Orange"-type capture magnet
  (Only captures one sign)