EDM Ring, Five Quads

lattice, orbit and spin tracking

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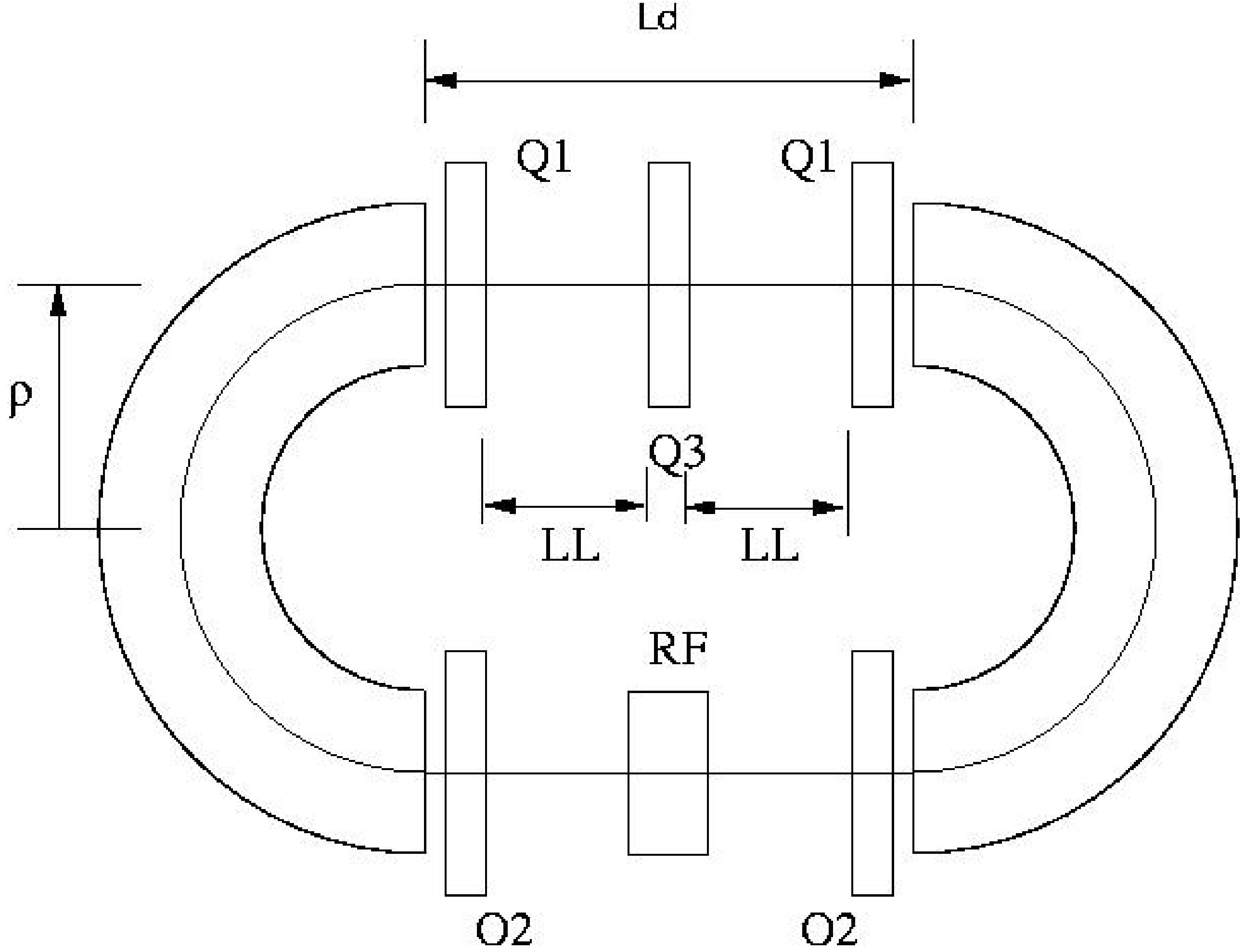
EDM ring with two magnets
B= 2T, n=1, α_p=1, footprint 5x10 meter^2

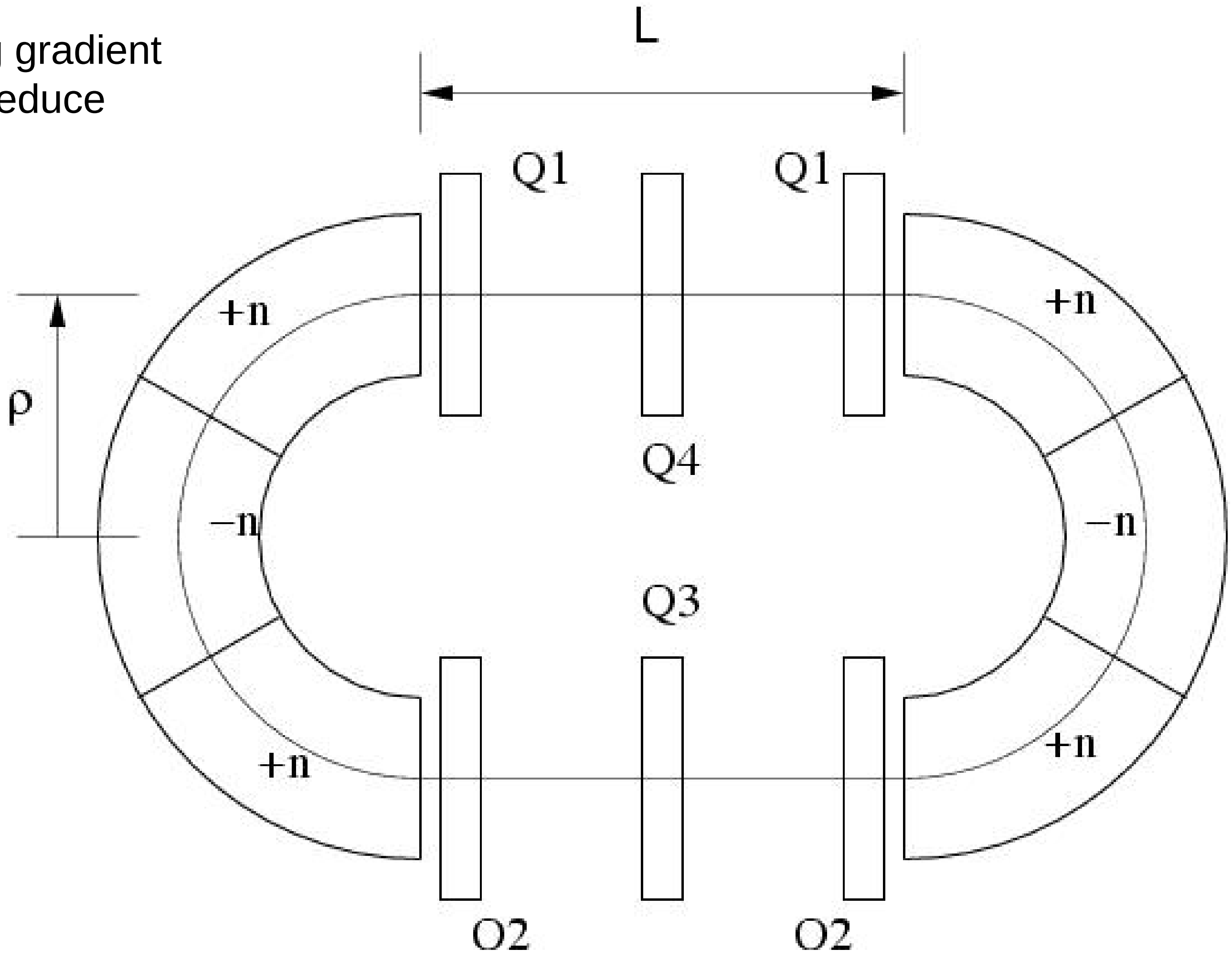
- Lattice optimized with *MAD* using a Montecarlo method
- At n=1 the ring is unstable to first order, but stable to second order: good enough for a ring operating at quasi fixed energy
- α_p=1 difficult to achieve. It freezes the size of the ring. Also, it produces a high dispersion in half of the ring

Five Fat Quads



Sector Bends

Alternating gradient
Bends to reduce
dispersion



FFQ parameters (1)

$pc = 1.5$ [GeV] (deuterons)

$\rho = 2.5$ [m]

$\gamma = 1.3414$

$\beta_s = 0.6665$

$B\rho = 5.003$ [Tm]

$B_0 = 2.00$ [T]

FFQ parameters(2)

$L_d = \pi\rho(\pi^2/6 - 1) = 5.0653$ [m] , drift length

$n = 1$, bend field index

$K1_B = -n/\rho^2$ [1/m^2] , bend quad strength

$L_Q = 0.32$ [m], quad length

$L_H = 0.08$ [m], quad-to-bend

FFQ parameters(3)

- $K1_{Q1} = 0.166512$ [$1/m^2$]
- $K1_{Q2} = 1.282920$
- $K1_{Q3} = -1.564187$
- $G1 = K1_{Q1}B\rho = 0.833136$ [T/m]
- $G2 = K1_{Q2}B\rho = 6.41904$
- $G3 = K1_{Q3}B\rho =-7.82635$

FFQ parameters(4)

total length = 25.838564 [m]

ν_x = 0.637806, hor. beta tune

ν_y = 1.182998, vert. beta tune

α_p = 1.00001, mom. compaction

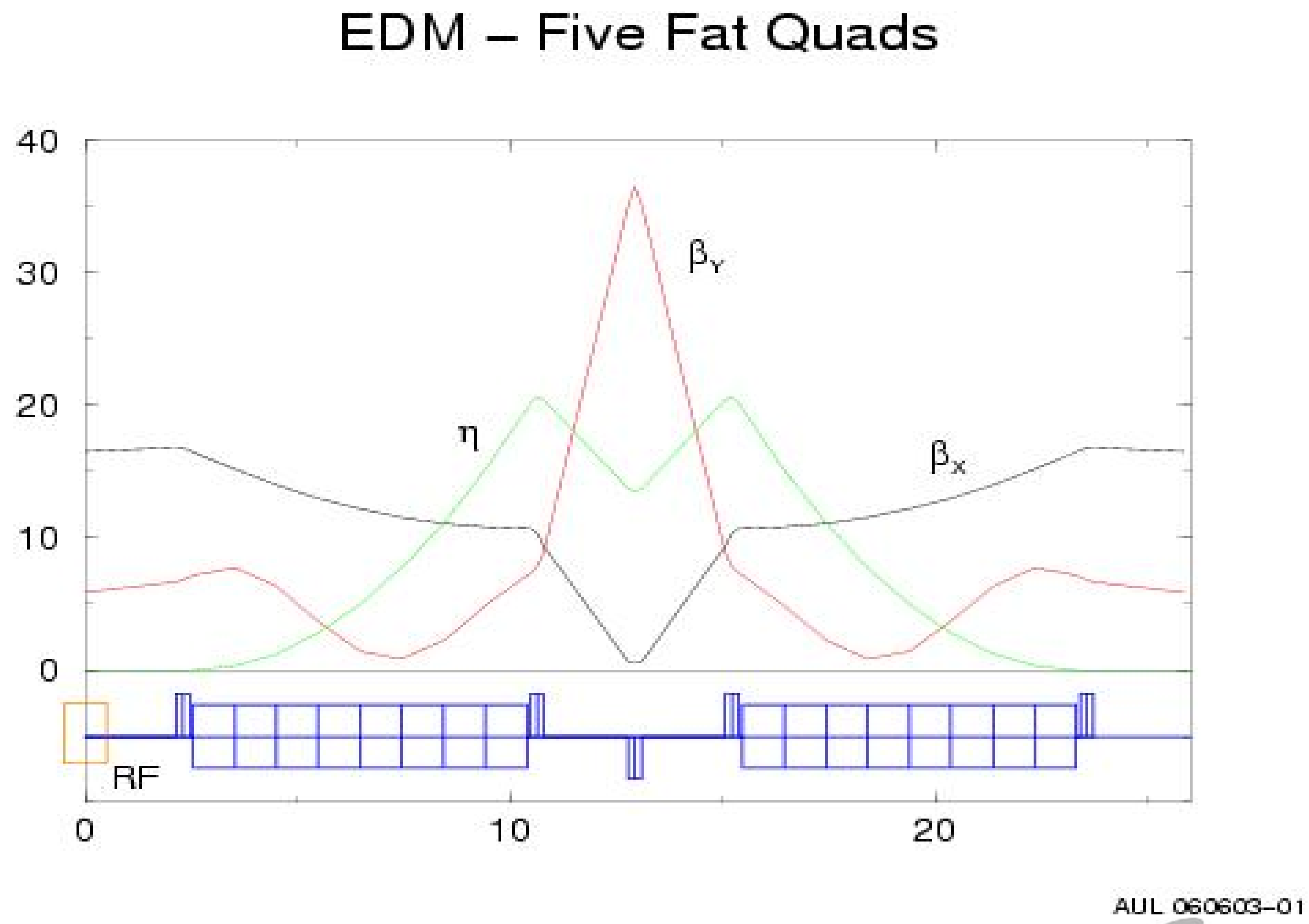
$\beta_{X,max}$ = 16.8168 [m]

$\beta_{y,max}$ = 36.5071 [m]

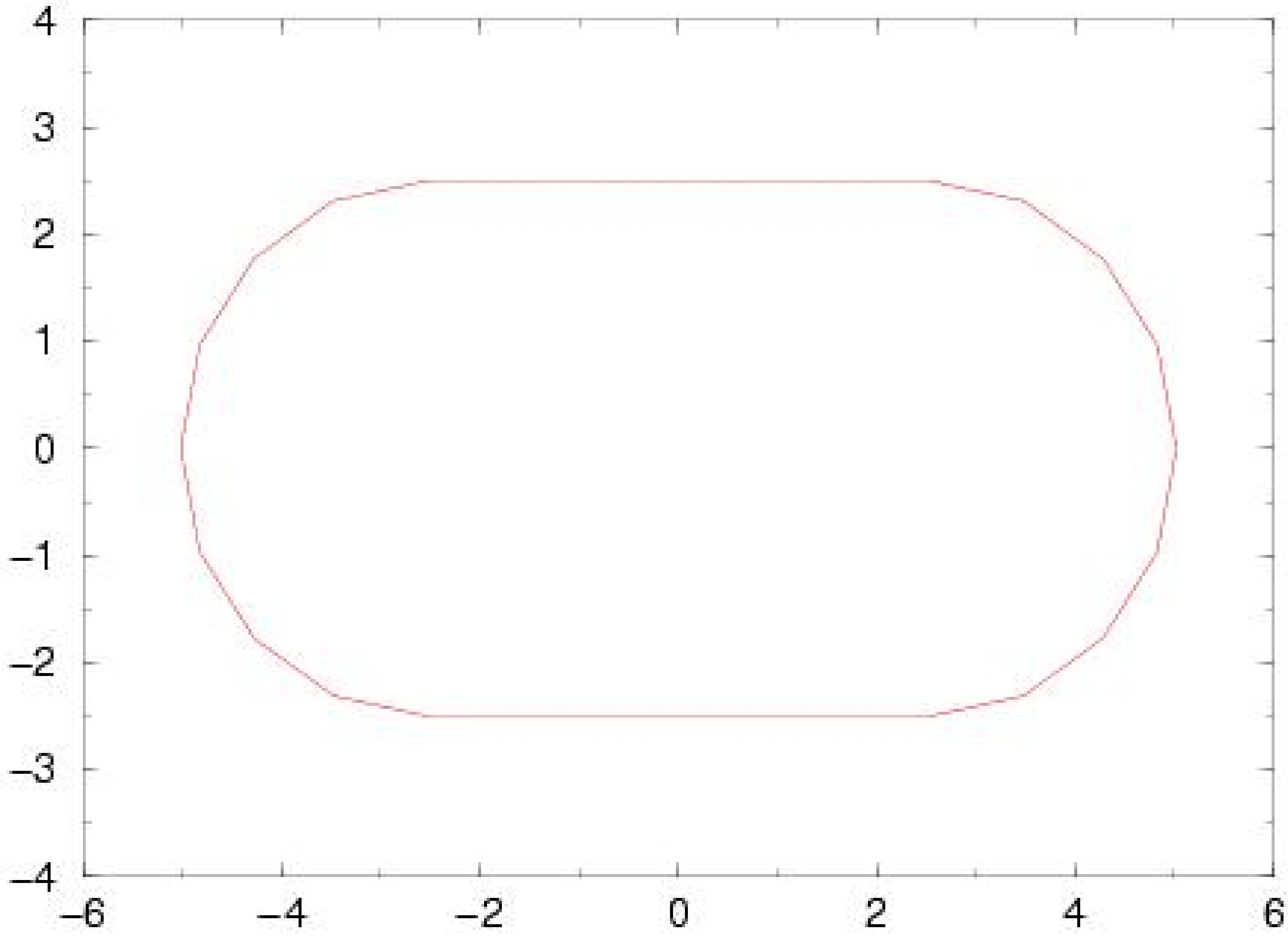
γ_{tr} = 0.999997, transition

$D_{x,max}$ = 20.6318, dispersion

Lattice (MAD)


EDM – Five Fat Quads
40
30
20
10
0
0
10
20
β_Y
η
β_X
RF
AUL 060603-01

EDM base line



Tracking (1)

Track polarized deuterons (magnetic), or, equivalent protons with energy close to an Intrinsic spin resonance

$$G\gamma = n + \nu_y$$

To check limits of spin stability. Cross the resonance by slow acceleration

FFQ tracking (2)

$1+G\gamma = 1.183$; $G = g/2-1$

$G(p) = 1.79285$, $G(d) = -0.14301$

$pc(p) = 1.3764$ GeV: $G\gamma(p) = [3].183$

$pc(d) = 1.4983$ GeV: $\gamma(d) = 1.2796$

$G\gamma(d) = 0.183$

search for spin resonance at n +/- 0.183

Accelerate in a RF cavity with V = 5 KV

Code Spink based on the BMT equation, modified to add edm

Tracking code *Spink*

Phase space propagation (thick elements)

$$r_i^{(n+1)} = \sum_{j=1,6} R_{ij} r_j^{(n)} + \sum_{j=1,6} \sum_{k=1,6} T_{ijk} r_j^{(n)} r_k^{(n)}$$

$$r_6^{(N+1)} = r_6^{(N)} + eV\left(\sin(hr_5^{(N)}) - \sin(\phi_s)\right)$$

Thomas-BMT equation for spin + EDM

$$\frac{d\vec{S}}{dt} = \frac{e}{\gamma m}\vec{S} \times \vec{F}$$

$$\vec{F} = (1+G\gamma)\vec{B}_{\perp} + (1+G)\vec{B}_{II} + \eta\vec{\beta} \times \vec{B}, \quad \vec{E} = 0$$

Spink

Rotation of a vector S by an angle μ around an axis b
(thin elements)

$$\frac{dS}{d\mu} = S \times b, or : S = RS$$

$$R = I\cos\mu + W(1-\cos\mu) + A\sin\mu$$

$$W = \begin{pmatrix} b_1^2 & b_1 b_2 & b_1 b_3 \\ b_2 b_1 & b_2^2 & b_2 b_3 \\ b_3 b_1 & b_3 b_2 & b_3^2 \end{pmatrix}, A = \begin{pmatrix} 0 & b_3 & -b_2 \\ -b_3 & 0 & b_1 \\ b_2 & -b_1 & 0 \end{pmatrix}$$

b,μ = f(B,G,η)

Spink

- *MAD ▬► mad_read ▬► symplectification*

▬► Sy_lattice descriptor (maps, twiss, errors)

Guarantees the conservation of invariants –say, Courant-Snyder- for several million of turns. Fast

- *MakePop▬► particle population in 6 D.*

Random Gaussian

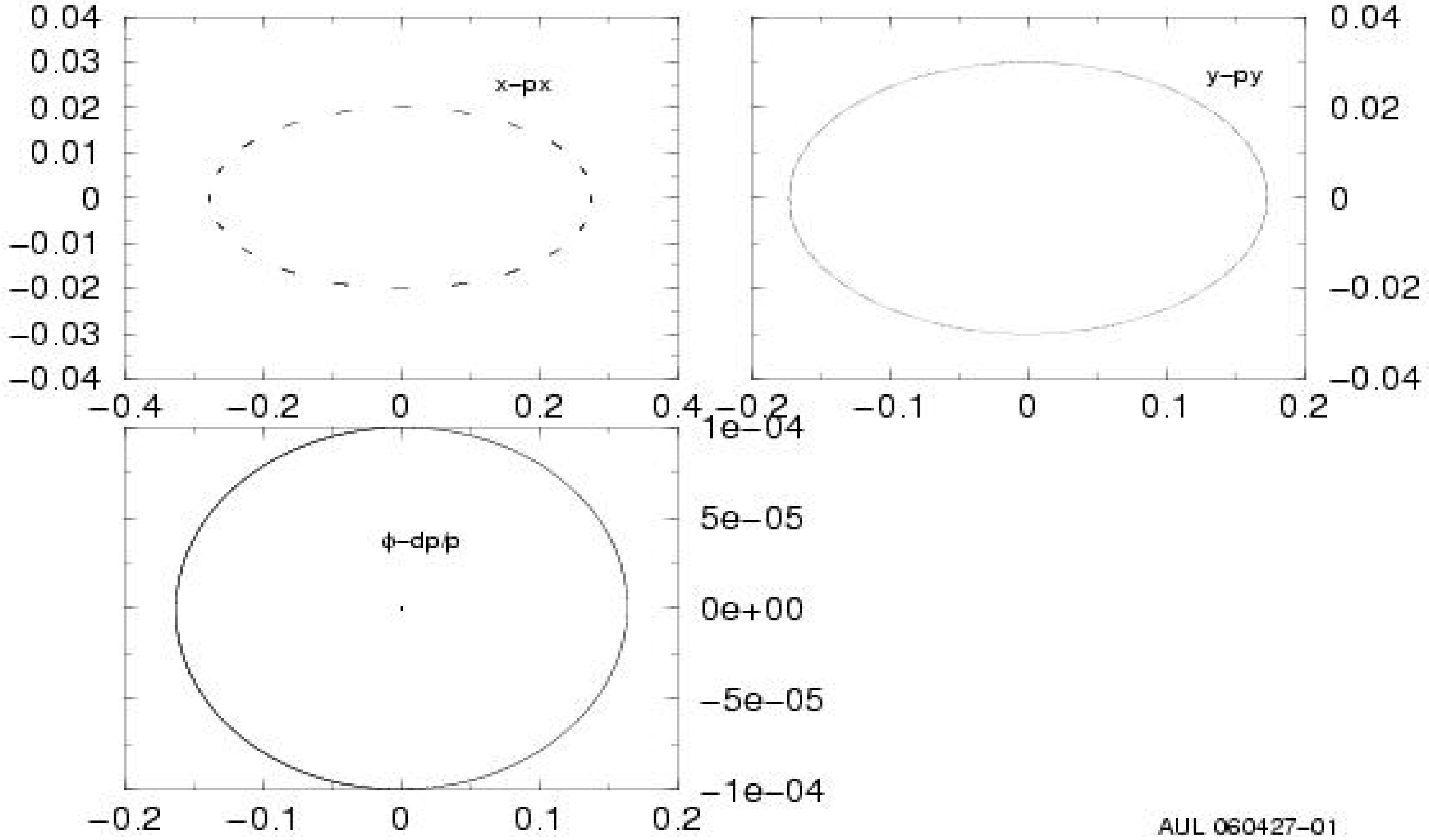
- *MPI directives ▬► parallelizazion (trivial)*

For many particle tracking

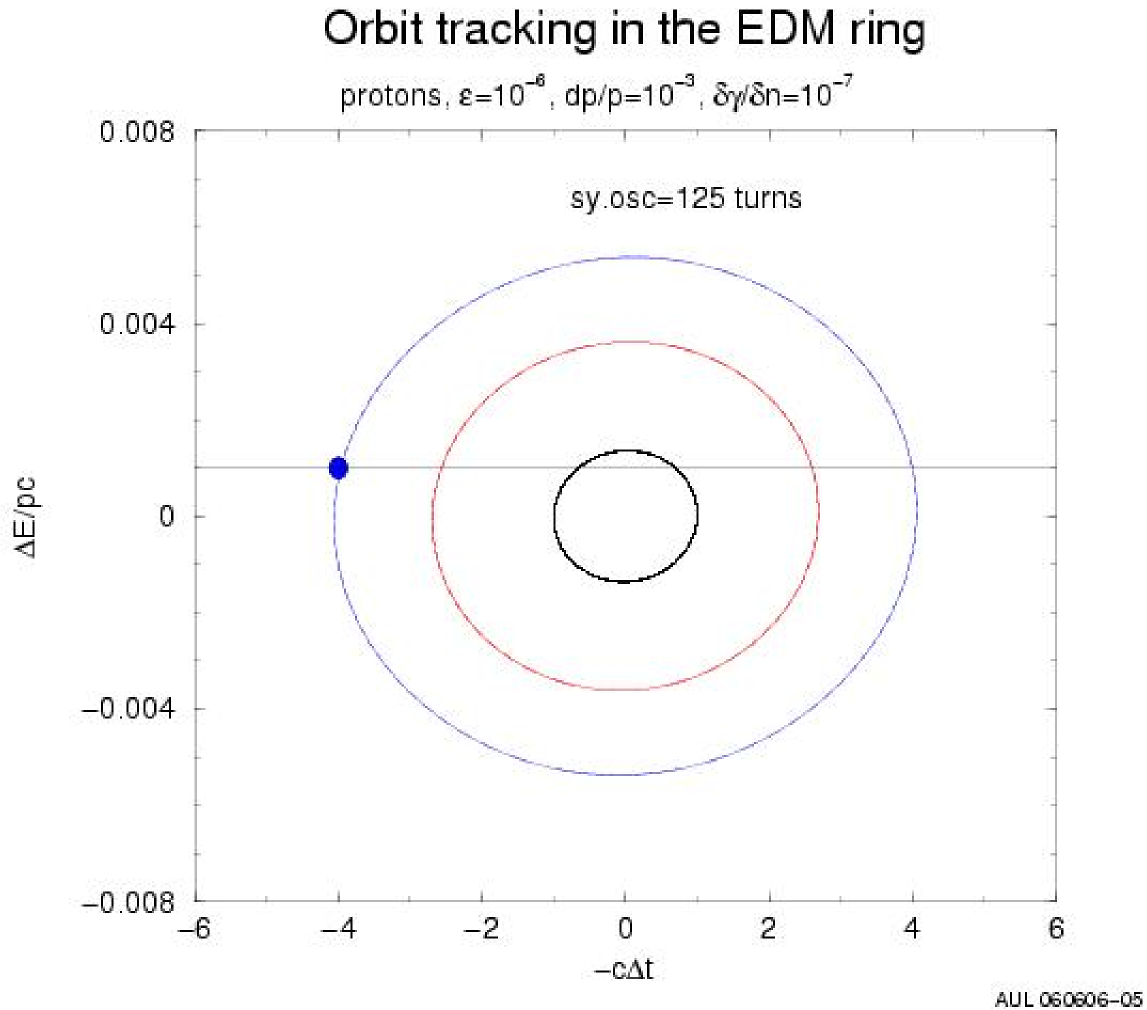
- *Sy + Pop + MPI ▬► Spink*

- *runs on Linux Cluster*

Transverse phase space
(to check symplecticity after many turns)



Longitudinal Phase Space



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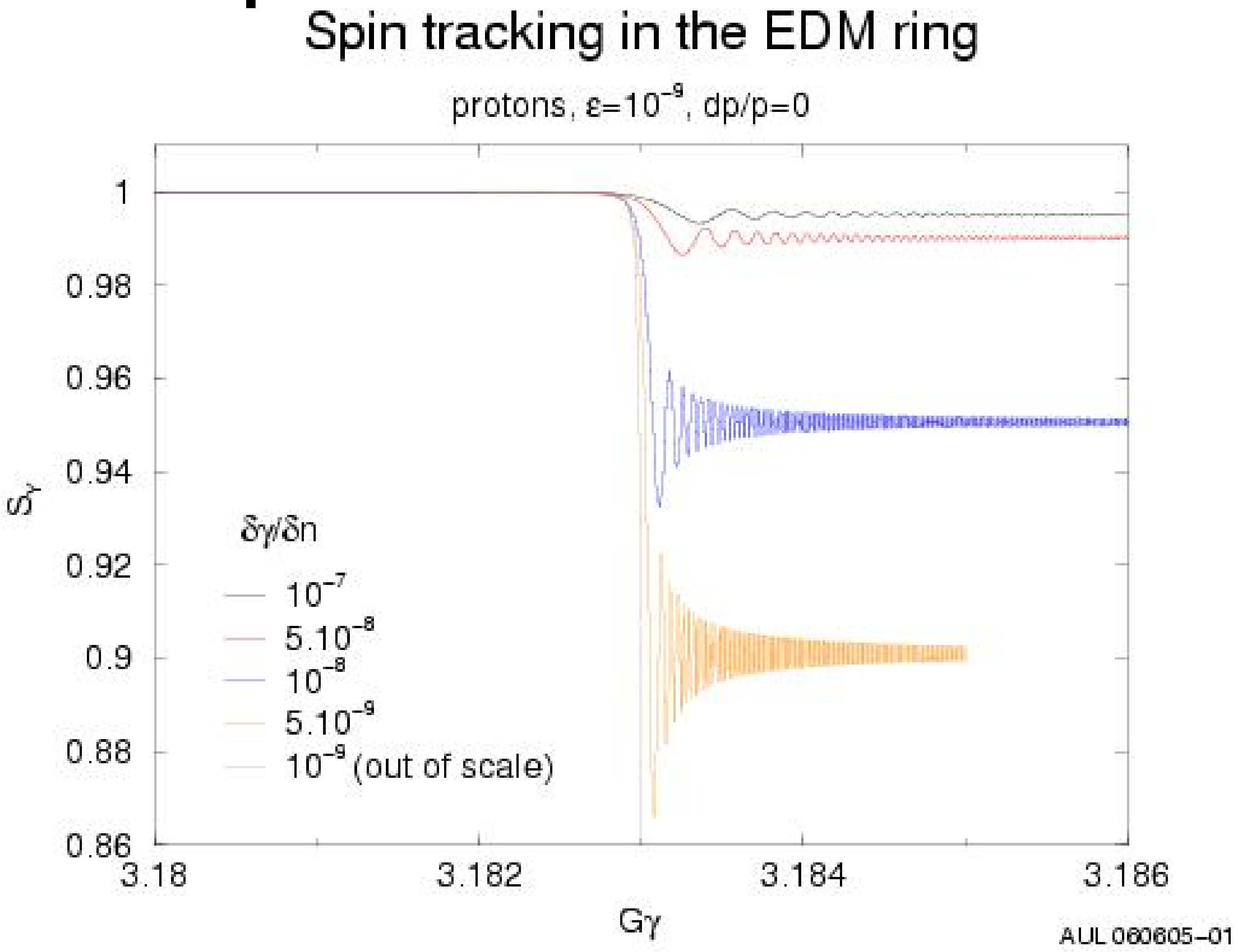
Track spin - resonance

Cross spin resonance at $G\gamma$=3.183

Various speeds of crossing

(for Froissart-Stora)

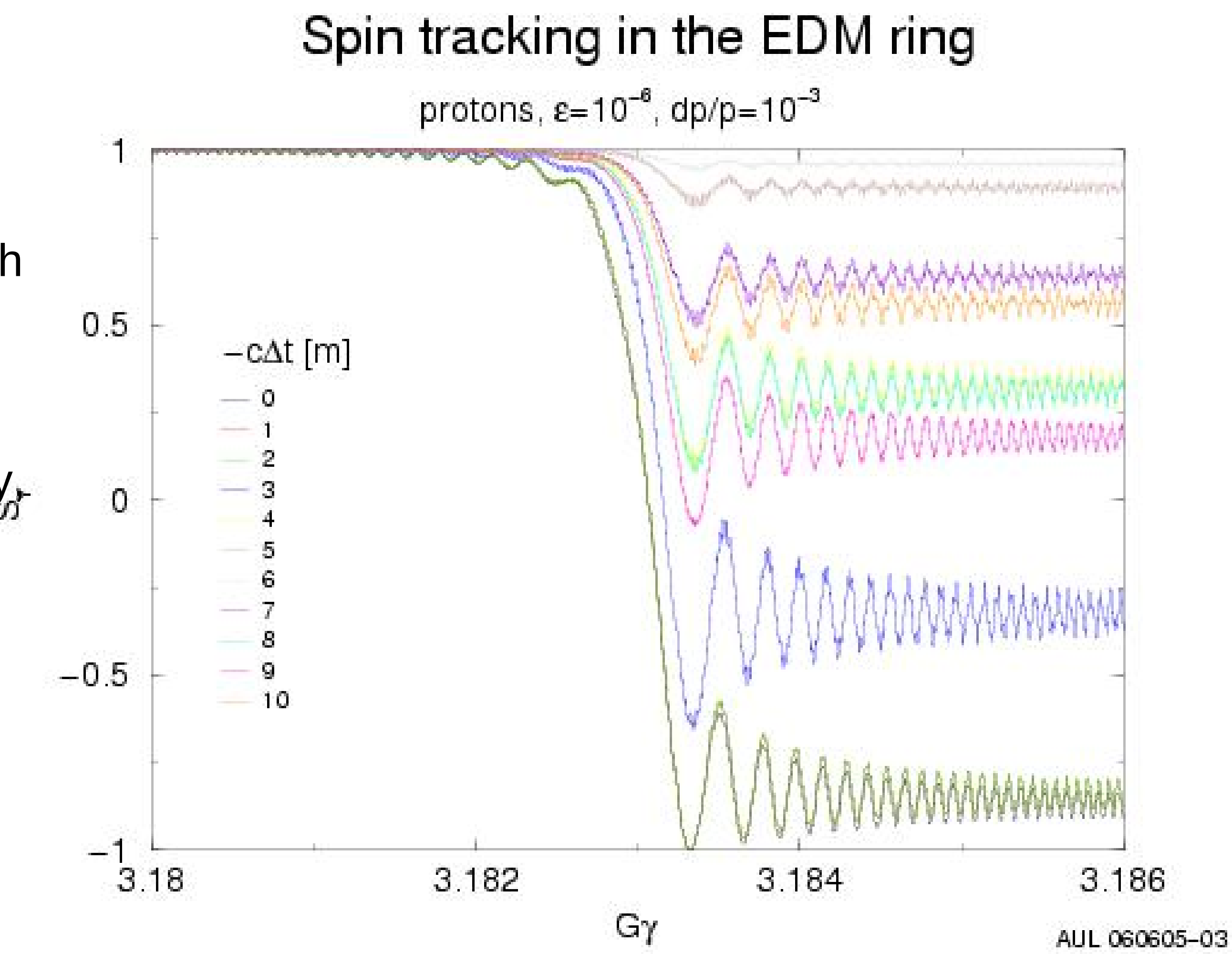
Represented is the vertical component of spin vs. spin tune $G\gamma$



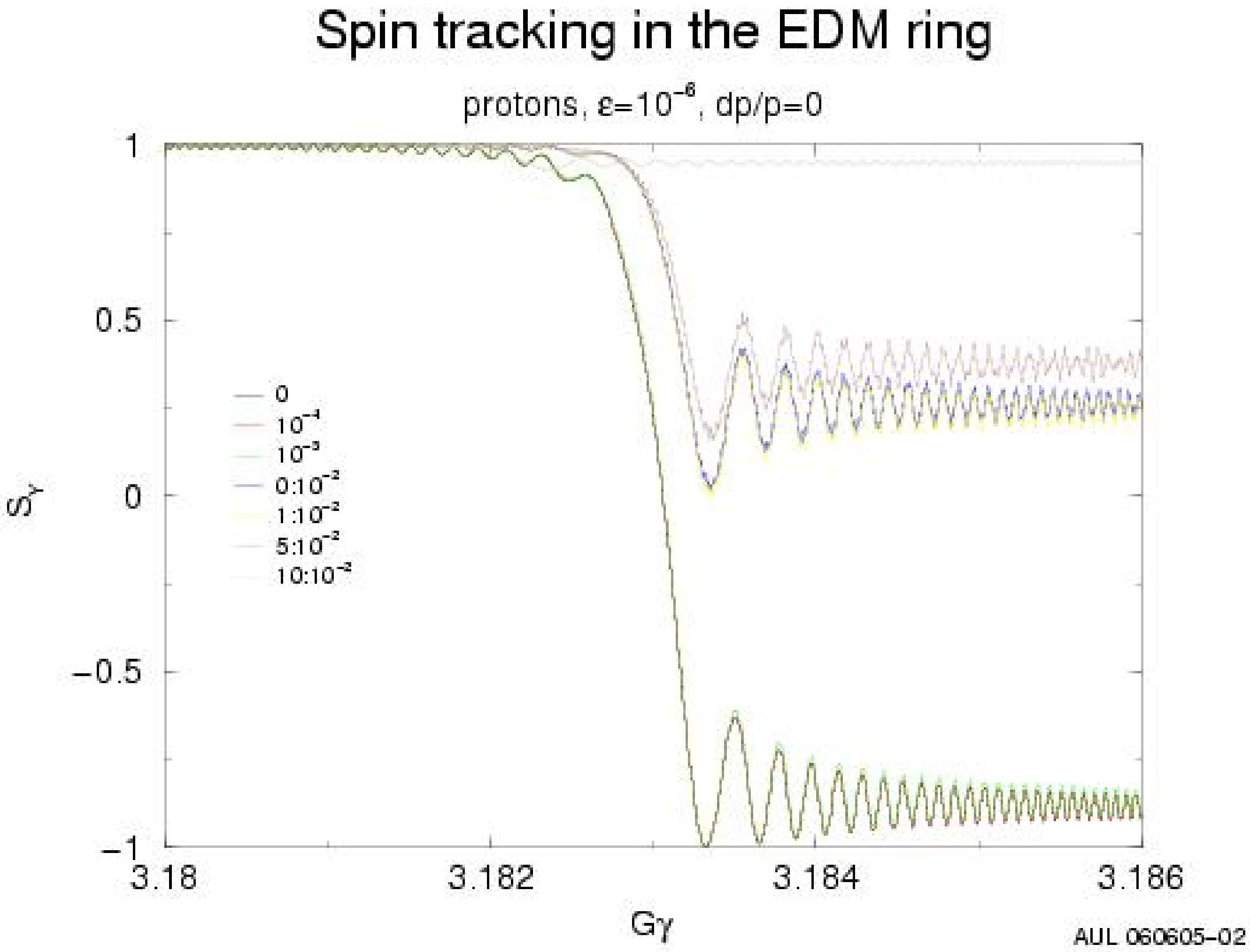
Various long. phases -cΔt

Track particles at various longitudinal position in the bunch

They cross the resonance differently, producing some depolarization



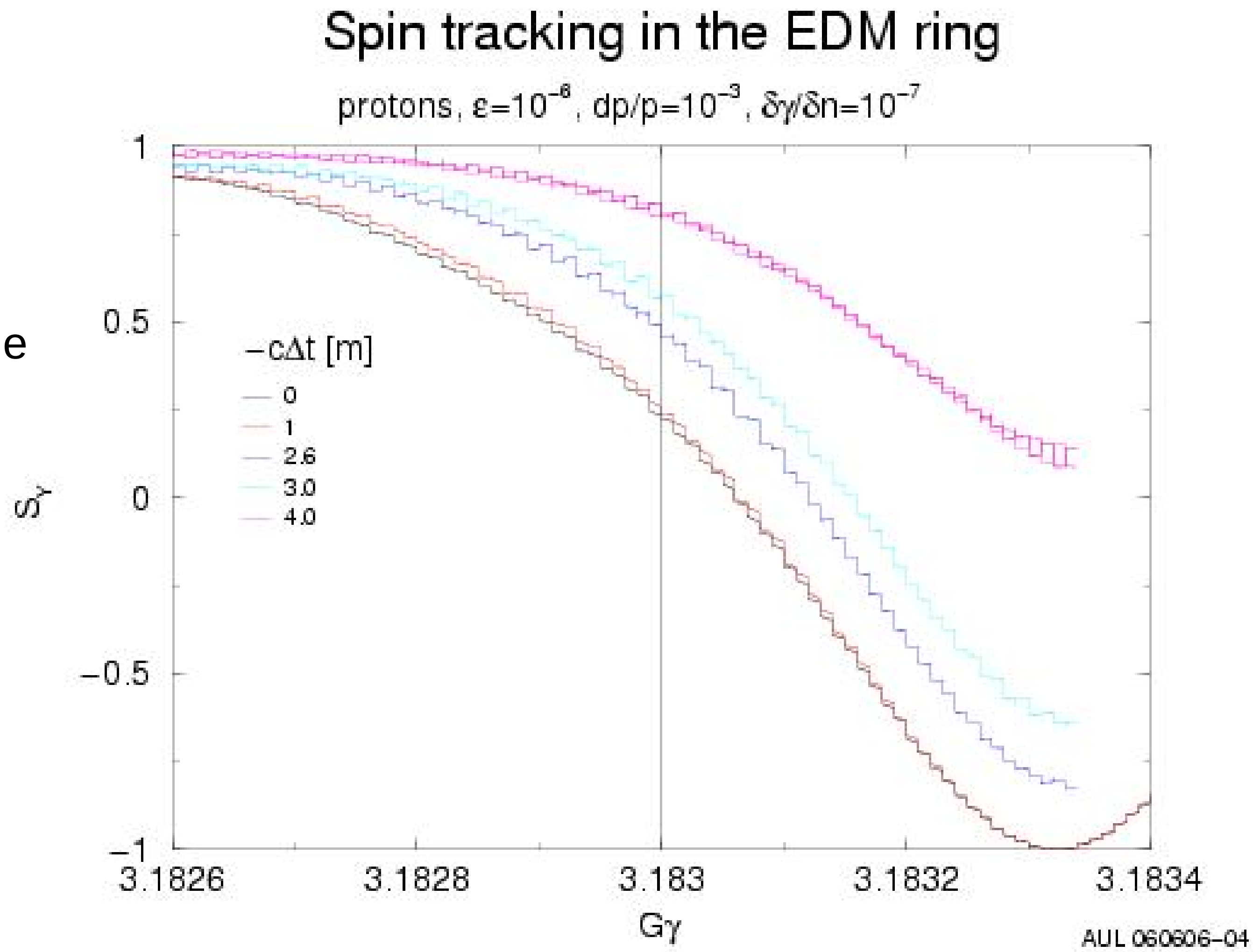
Spin resonance- vary: -cΔt



Some more of the same……

Various –cΔt (2)

Central part of the bunch.
Particles up to 4 m away from the synchronous particle



Particles within a 1 m long bunch behave coherently

Vertical component of the spin. Injection with spin longitudinal.Tilt of 10-3 rad of quadrupole Q2. Vertical motion suppressed. 10^6 turns