Super-B spin studies at LPSC status report 03 2010

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Abstract

We give an overview of where we are now in our work at LPSC, Grenoble, mainly regarding polarization.
- Reviewing the methods of the Zgoubi tracking code
- Spin simulations for LER
- Then last code developements.
I also introduce some question I have along the presentation.

Contents

1 Spin tracking for spin dynamics studies

1.1 Motivation

Physic's people want a polarised beam and may want high accuracy knowledge of polarisation at IP, but we do not (because we can not?) measure polarisation at IP.
We measure it somewhere else (π spin-precession downstream).
So we

- need to design a ring with the highest polarisation degree we could reach, taking into account other constraints.
- need to understand really well how evolves spin between IP and the point of measure (compton IP), and of course also in the whole ring
- need to understand really well how it evolves within the bunch.

1.2 Zgoubi's method

- a **numerical method** for stepwise integration of Lorentz equation of motion,
  - based on Taylor series,
  - which optimizes computing time
  - provides high accuracy and strong symplecticity,
  - **NOT** a matrix method
- includes **spin tracking**,
  - using the same Taylor-series based numerical method
- also includes calculation of **synchrotron radiation**
  - loss and effects on particle dynamics
  - *(not strictly relevant here : electric field and spectra)*

The code, guide, 'zpop' graphic and treatment interface, are maintained on and downloadable from SourceForge (google : "SourceForge Zgoubi"). Details on integration method available in user´ s guide

1.3 few necessary theoretical consideration

- **Spin motion is governed by :**

Thomas-BMT equation

$$\frac{d\vec{S}}{dt} = \vec{\Omega} \times \vec{S} \qquad (1)$$

where :

$$\vec{\Omega} = -\frac{e}{mc}[(a + \frac{1}{\gamma})\vec{B} - \frac{a\gamma}{\gamma+1}(\vec{\beta}(\vec{\beta} \cdot \vec{B})) - (a + \frac{1}{\gamma+1})\vec{\beta} \times \vec{E}] \qquad (2)$$

Spin n-vector $\vec{n}_0$

- **Also called 'spin closed orbit', is the local precession axis of particle spin. It can be understood from two equivalent point of view :**
  - **$\vec{n}_0$ is one eigenvector of a spin transport matrix over one turn (matricial point of view).**
  - **$\vec{n}_0$ is one spin vector that has the same initial and final coordinates (after one turn tracking without synchrotron radiation) (tracking point of view).**

- **$\vec{n}_0$ is stable over turns, which means that if a particle is injected on closed orbit with its spin following this axis, this particle spin will still be aligned after one turn (as long as we do not take into account synchrotron radiation)**

- **$\vec{n}_0$ vary with : Energy, Position. Spin motion depends strongly on orbital and synchrotron motion.**

1.4 WARNINGS

• **Every following results is only an illustration of what we could now routinely do.**

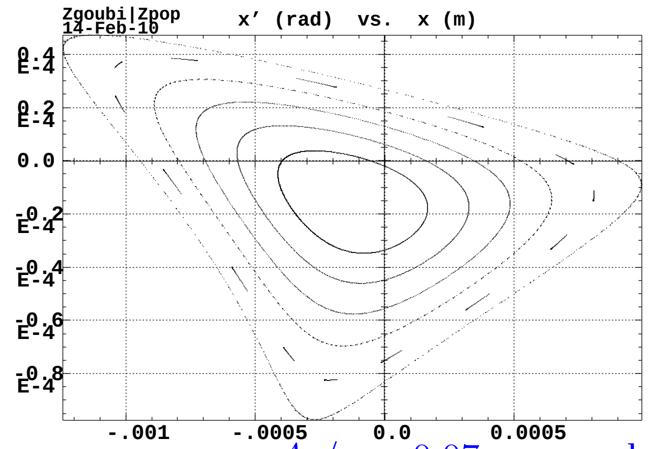
• **Please keep in mind that we look for strong agreement with MAD lattice function*, so our present Zgoubi lattice is liable to slight changes until we are satisfied and get a more or less 'final and fix' lattice (until then, we'll develop the tools)**

• **Please note also that we use V11 lattice with fixed solenoid (see slide dedicated to solenoids).**

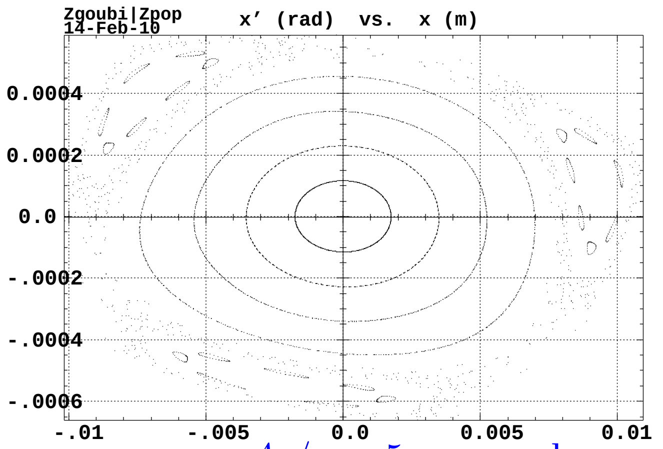
*** I don't put our simulations results here, to focus on spin results.**

1.5 beam dynamics : maximum stable amplitudes

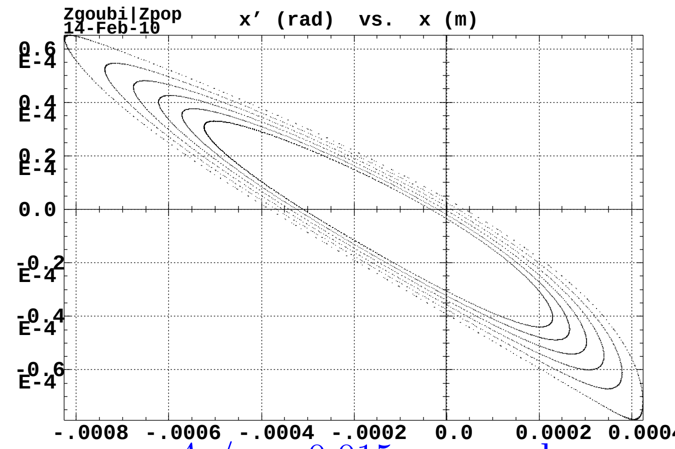
HER, 1000-turn maximum stable amplitudes



$A_x/\pi \approx 0.07$ mm.mrad

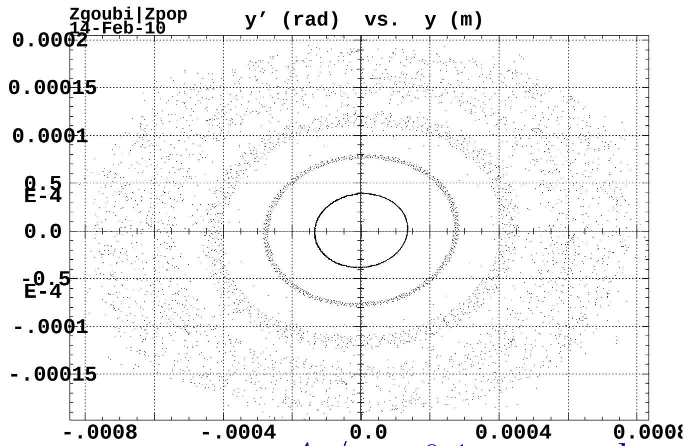


$A_x/\pi \approx 5$ mm.mrad

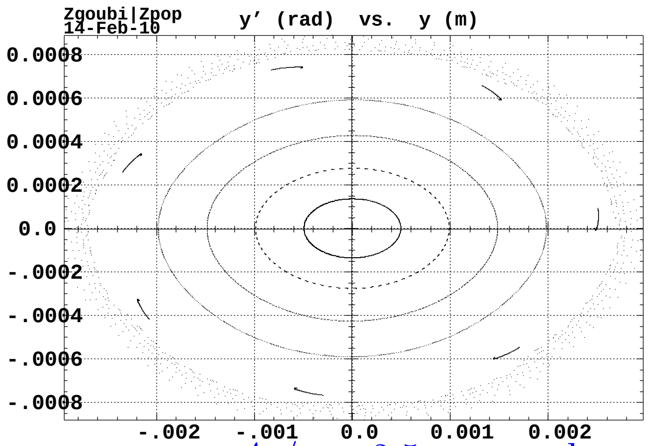


$A_x/\pi \approx 0.015$ mm.mrad

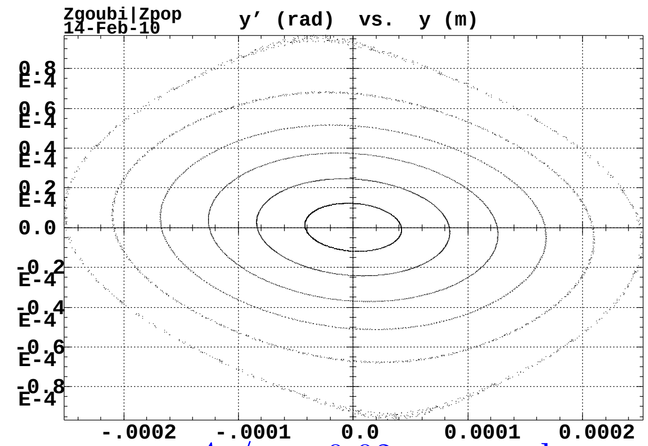
Maximum stable horizontal amplitude (pure horizontal motion), at $\delta x = 1\ \mu$m precision, observed at middle RF, $dp/p_0 = -1,\ 0,\ 1\%$ from left to right.



$A_y/\pi \approx 0.1$ mm.mrad



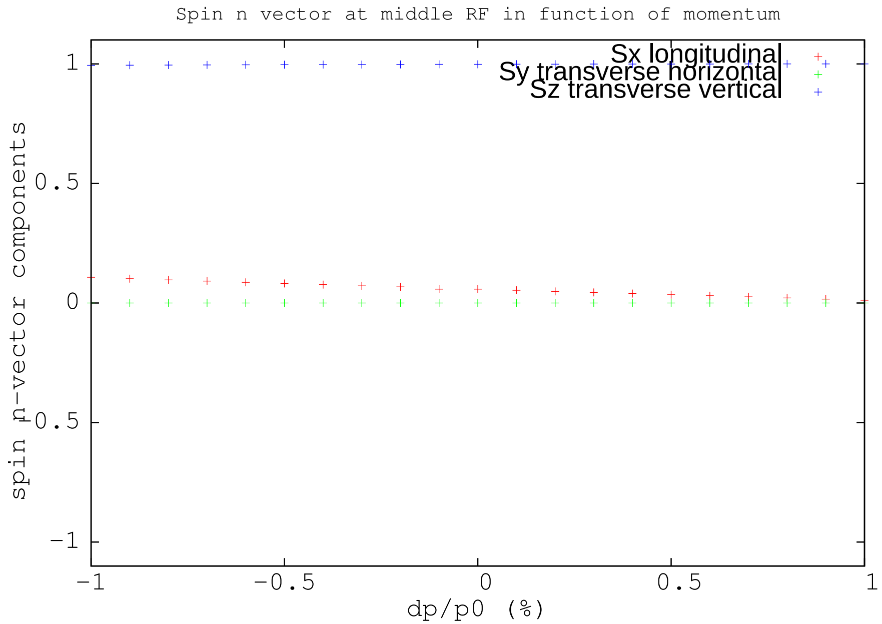
$A_y/\pi \approx 2.5$ mm.mrad



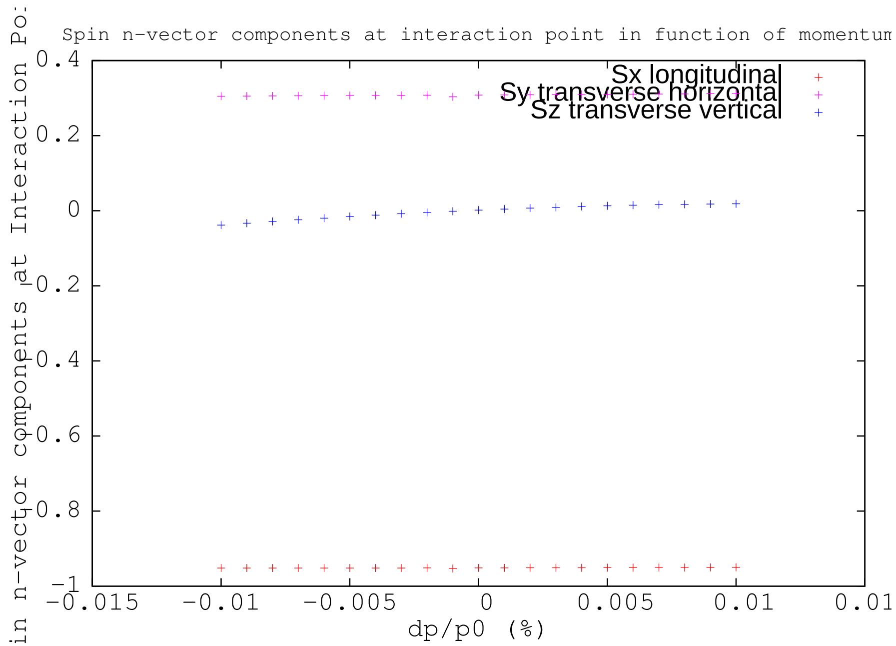
$A_y/\pi \approx 0.02$ mm.mrad

Maximum stable vertical amplitude, at $\delta y = 1\ \mu$m precision, observed at middle RF, $dp/p_0 = -1,\ 0,\ 1\%$ from left to right. Coupling to horizontal motion is observed in the $dp/p = -1\%$ motion.

1.6 $n_0(\delta)$, evolution of 'spin closed orbit' with momentum



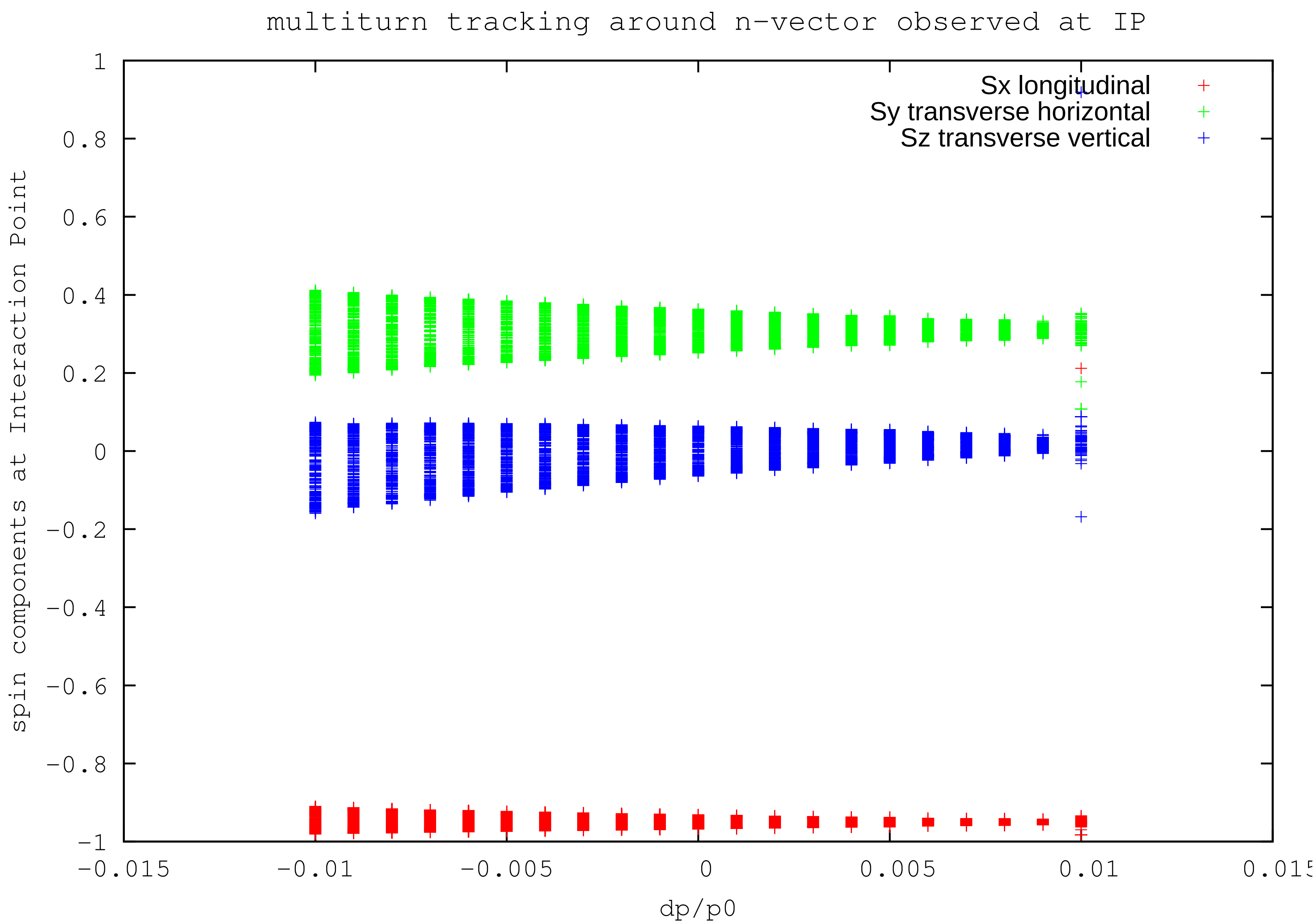
$\vec{n}_0$ components at injection (middle RF) in function of momentum



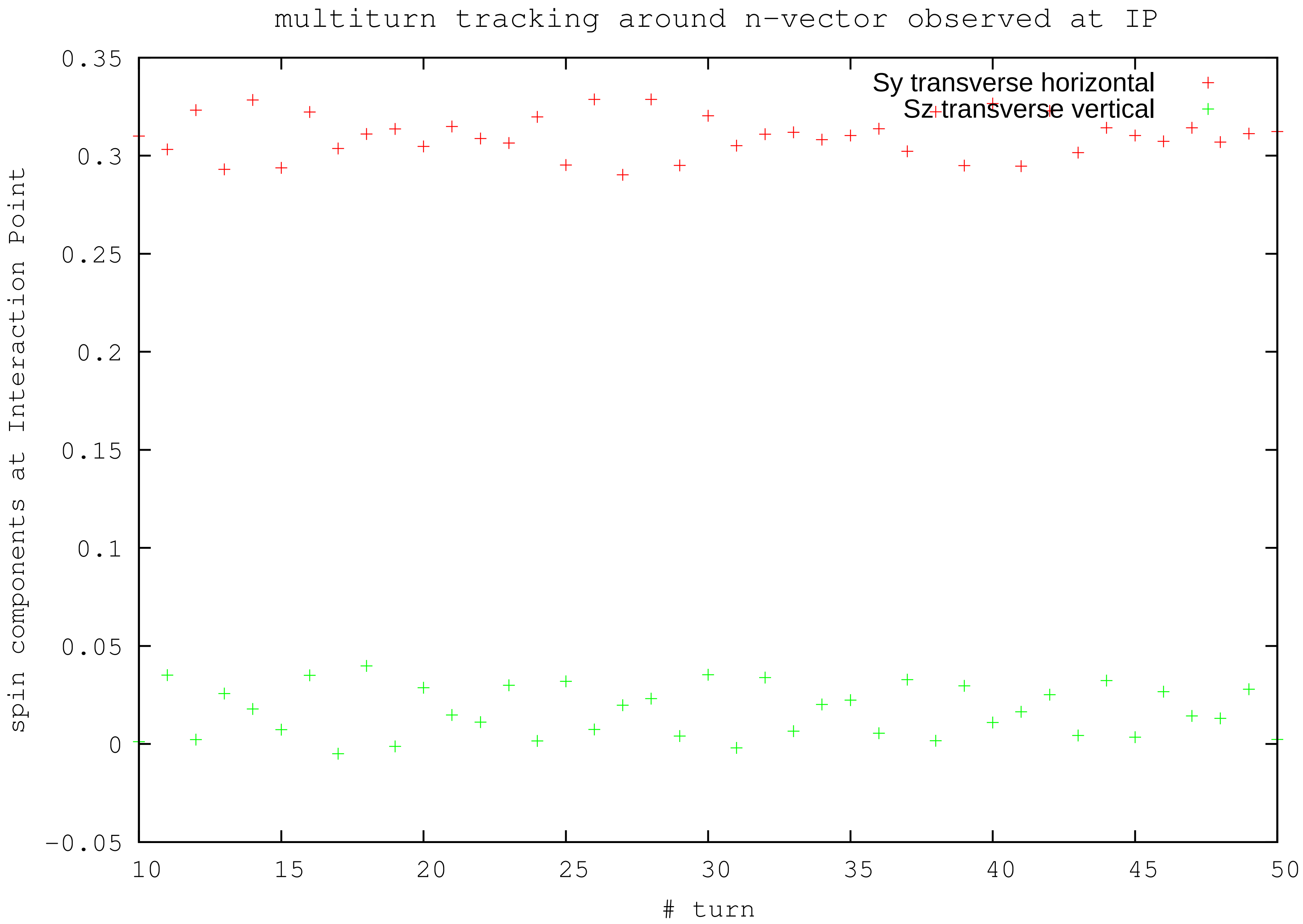
$\vec{n}_0$ components at IP in function of momentum

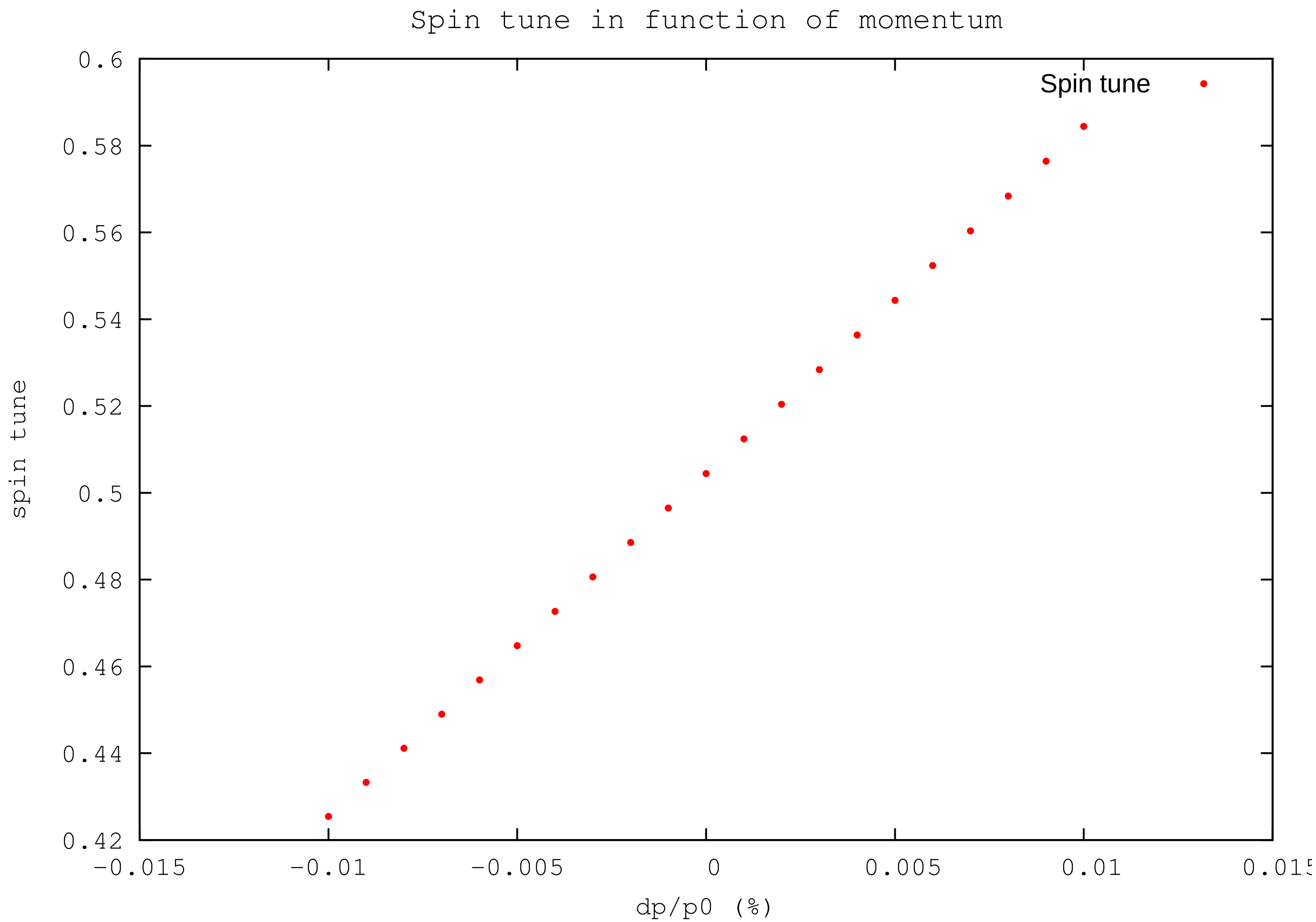
- We want $\vec{n}_0$ longitudinal at IP (on upper graph Sx=1 or -1, Sy=0, Sz = 0). It's not the case, because IP seems not to be in the middle of the rotator. The spin precess a little bit too much (he precess more before IP than after).
- We also want $\vec{n}_0$ to be (0,0,1), i.e. vertical, in the rest of the ring. It's also not *exactly* the case, due to a small 'wrong' energy or total bending between Left and Right rotators. With $\frac{dp}{p} = +1.19\%$ it's ok. Should we adjust the lattice or rescale a little bit the energy?
- To find $\vec{n}_0$ with zgoubi, we run a matching ('FIT') process which find initial coordinates that are the same after one turn.

- **So if we inject with a pure vertical spin, we get oscillation around $\vec{n}_0(\delta)$**



Spin observed at IP, for a series of $\delta = dp/p$, for pure vertical ($\vec{S} = (0, 0, 1)$) injection, multi-turn tracking


multiturn tracking around n-vector observed at IP
spin components at Interaction Point
turn
Sy transverse horizontal
Sz transverse vertical
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
10
15
20
25
30
35
40
45
50

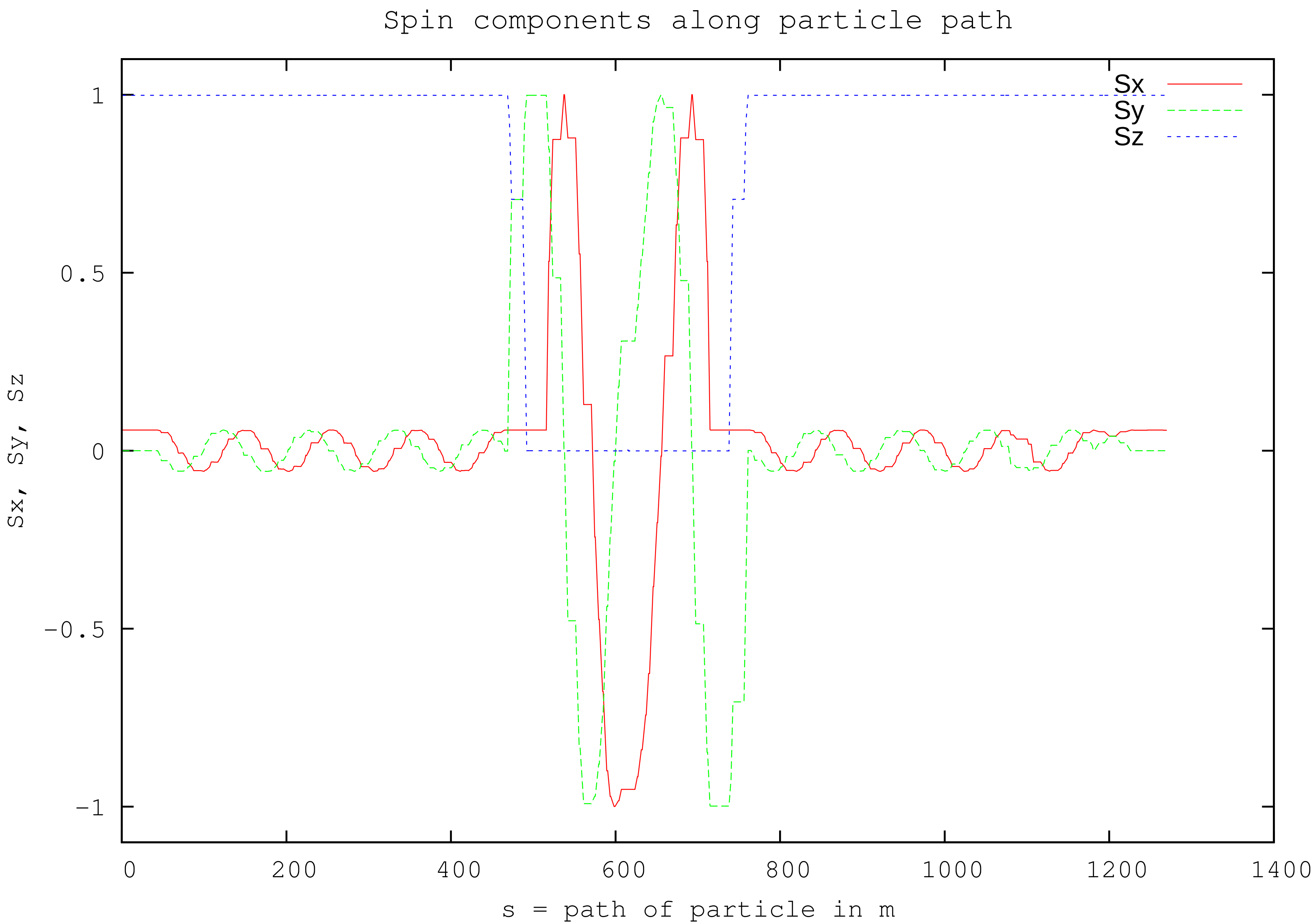


- **What I called fractionnal spin tune here is :**

$$\frac{acos((S_x0.S_x1 + S_y0.S_y1 + S_z0.S_z1)/(\|S_0\| * \|S_1\|))}{2\pi} \tag{3}$$

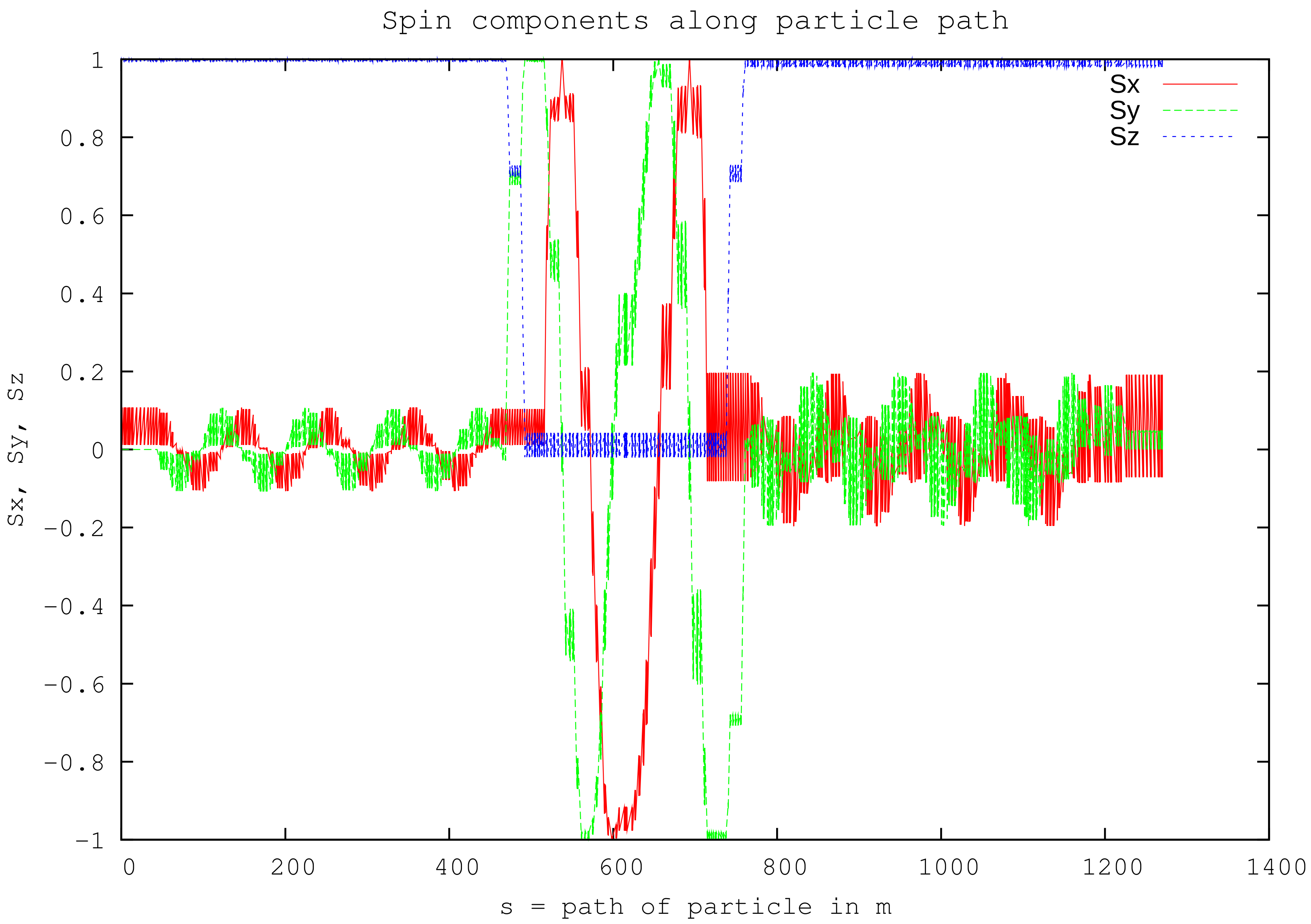
if $S_x1 > 0$ and $1 - ...$ if $S_x1 < 0$. This an approximation, almost valid because $\vec{n}_0$ is nearly vertical (at least it is in the (x,z) plane) and I track $\vec{s} = (0,1,0)$ particles

1.7 Spin along elements

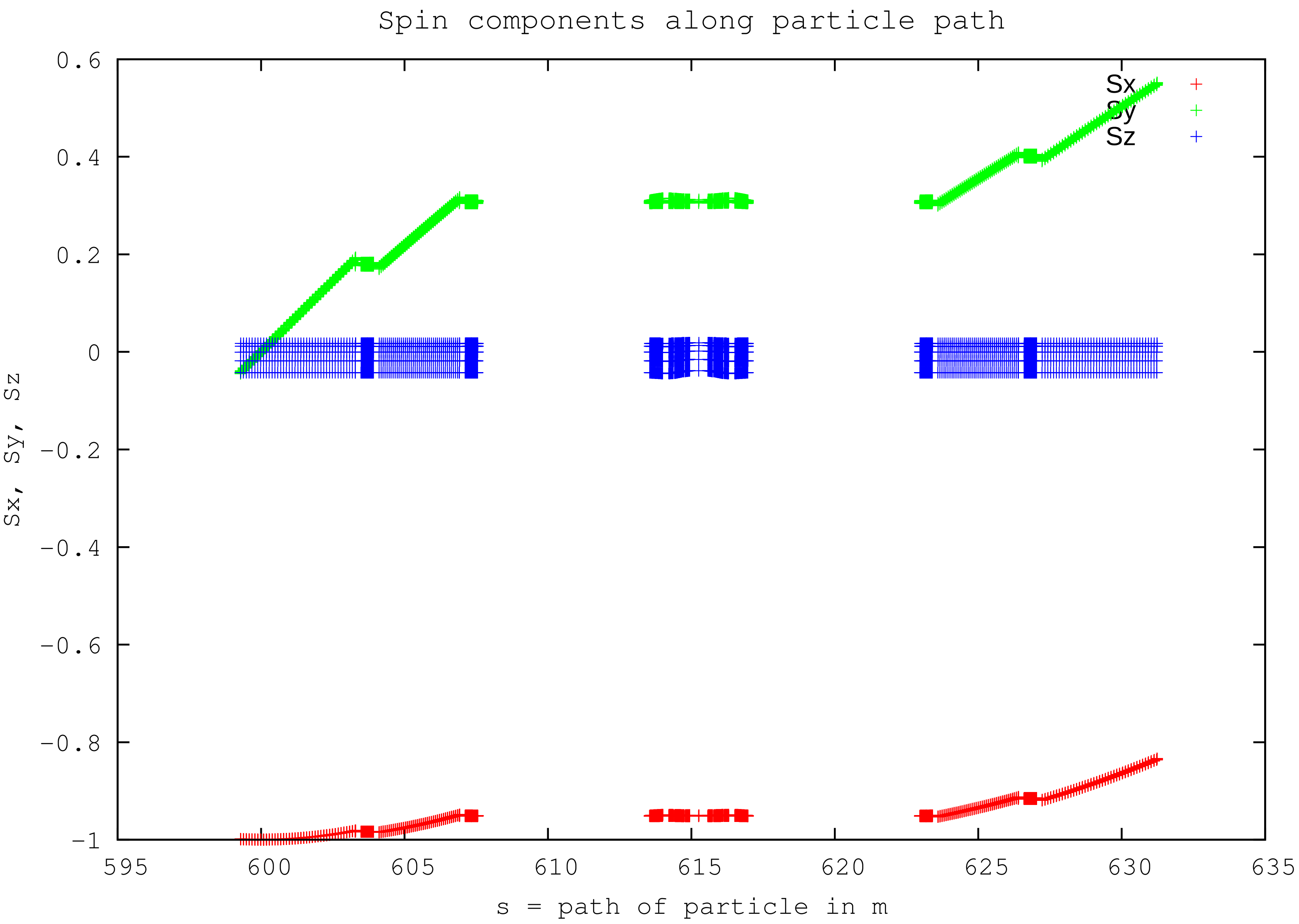


single-turn tracking for $\vec{n}_0$ on momentum.

slide 12



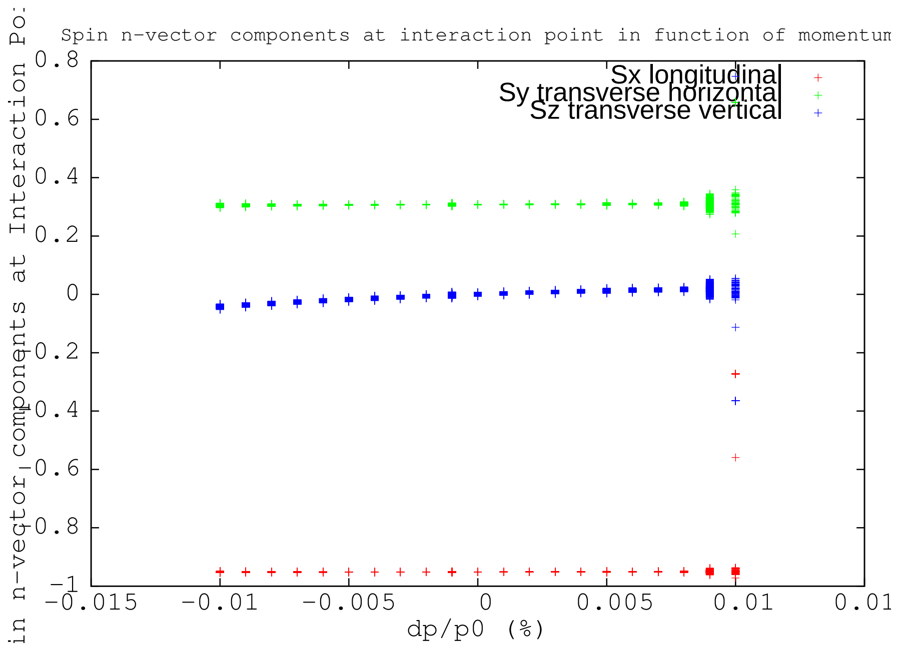
single-turn tracking for $\vec{n}_0$ for 5 different momenta (-1%, -0.5%, 0%, +0.5%, +1%)



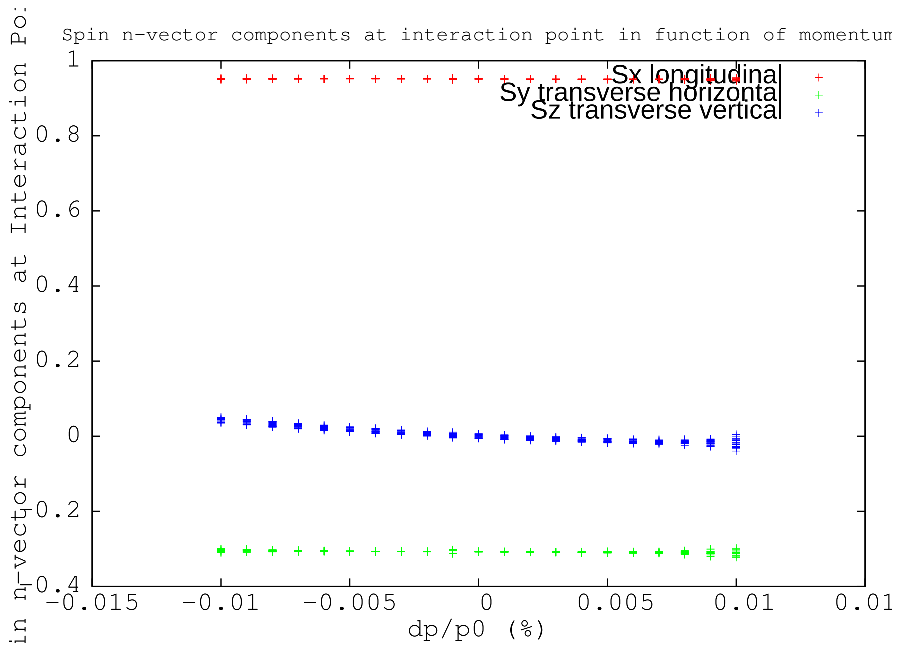
zoom on $\vec{n}_0$ around IP

1.8 up & down tracking

Here I track up and down oriented (refered to n_0 spin vector) spin to see what happens. As long as we do not take into account Sokolov-Ternov, the results of this simulations should be symmetric (and they are !).



spin oriented following $\vec{n}_0$ at injection, multi-turn, observed at IP



spin oriented following $-\vec{n}_0$ at injection, multi-turn, observed at IP

2 Related code developpements & Work in progres

2.1 Zgoubi

2.1.1 Modification of the code

- **We are working at adapting the main data output to fulfill spin study requirements.**

- **We implemented a new (simpler) model for superB rotator solenoids, next paragraphe.**

- **Acceleration cavity & SR loss do work, independently. Next step is to get it working together. This will allow spin diffusion.**

- **Working at data input/output to fulfill guineapig requirements.**

- **We plan to implement Sokolov-Ternov effect (relevant ?). Any contributions or suggestions are welcome.**

2.1.2 New solenoid model

We pointed out some inconsistency in our solenoid model, specially on paraxial condition ! so we implement a new, simpler model, which is in good agreement with MAD's hard edge when taking very small radius, as we could see in this transfert matrices. So we are happy with it for MAD comparison.

solenoides transfert matrices :

0.961980	2.132060	0.191246	0.423863	0	0
-0.017155	0.961980	-0.003410	0.191246	0	0
-0.191246	-0.423863	0.961980	2.132060	0	0
0.003410	-0.191246	-0.017155	0.961980	0	0
0	0	0	0	1	0
0	0	0	0	0	1

solenoide transfert matrix from MAD.

0.961986	2.13206	0.191247	0.423863	0	0
-1.714866E-02	0.961986	-3.409229E-03	0.191247	0	0
-0.191247	-0.423863	0.961986	2.13206	0	0
3.409229E-03	-0.191247	-1.714866E-02	0.961986	0	0
0	0	0	0	1	0
0	0	0	0	0	1

solenoide transfert matrix from Zgoubi axial field model in short edge condition

• For further studies, we must improve this model and go through deep verification (check behaviour with realistic radius, fringe field, and so on...).

2.2 Interfacing Zgoubi with Guineapig++

Motivation

- get a strong-strong beam-beam simulation suite that take into account the ring
- or get a tracking code that take into account beam-beam effect
- is precise simulation of non-linear effects from ring crucial ?
- could be first step before a simplified beam-beam element in zgoubi ? usefull ?

Work in progress

- understand the transposition between Zgoubi and GP reference frames
- write a little note on these developements
- small bash-tools to run both codes one after the other (close to end, matter of days)
- how should I go from ”degree of polarization” to ” spin components”?

Difficulties

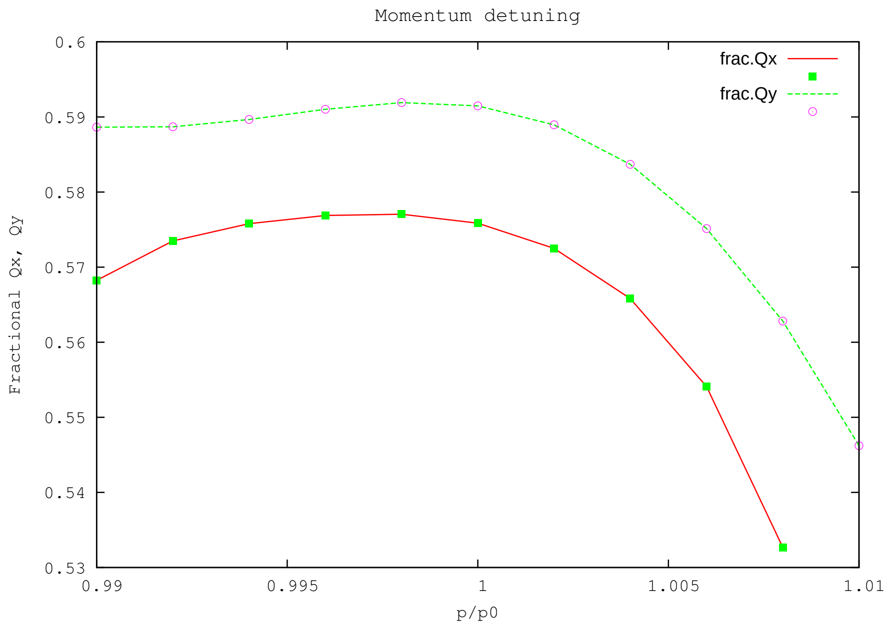
- some tracking simulations will be time consuming, at least for computer
- but it seems we all have a lot of unused computer (GRID, farms...) !
-

Thank you for your attention

BACK UP

slide 22 **Beam dynamics**

- **nothing really original/new here since december. we performed the same kind of study we did for V8 (DA, momentum detuning, comparison between zgoubi and mad for tracking in hard edge condition). The main evolution is that I can do it really much faster!**
- **reasons are :**
  - **As I told, we discover a problem in our solenoid model when we began spin studies. We solved this**
  - **V12 arrived**
  - **We prefer to devellop tools for spin**
  - **We worked on Zgoubi/Guineapig interface**



Momentum detuning LER V12 from Zgoubi. Comment : 1 point missing at +1% , why?