

Spin studies status report, LPSC Dec. 2011

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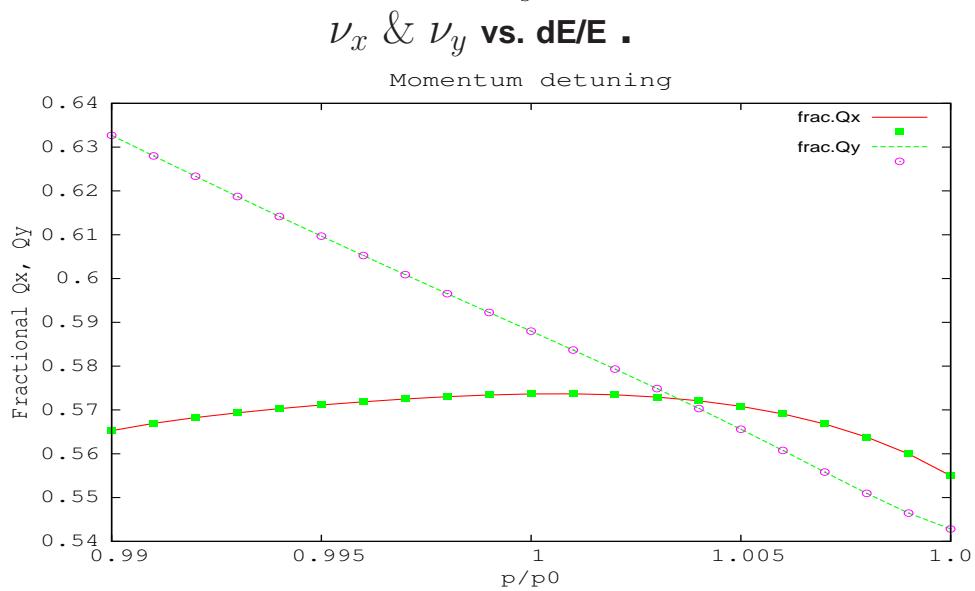
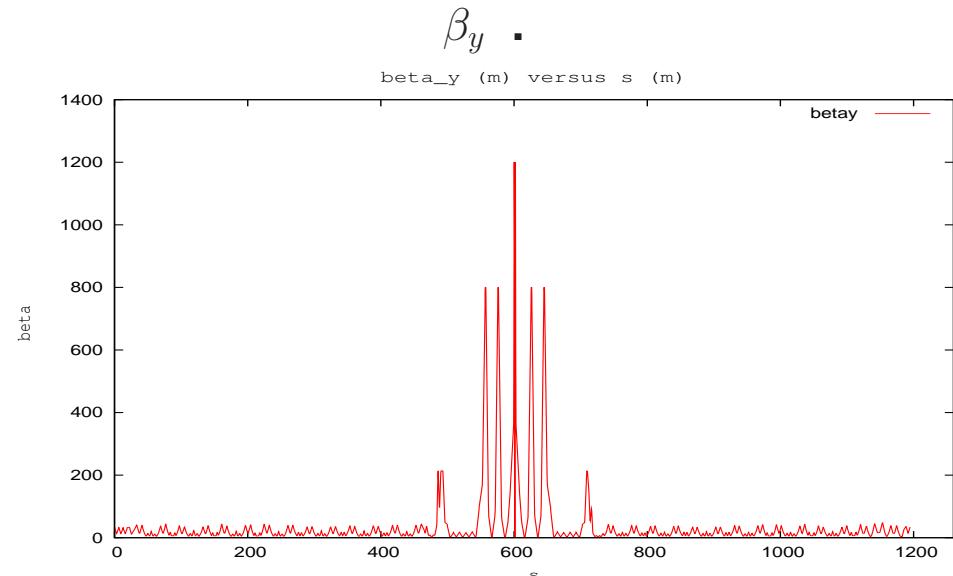
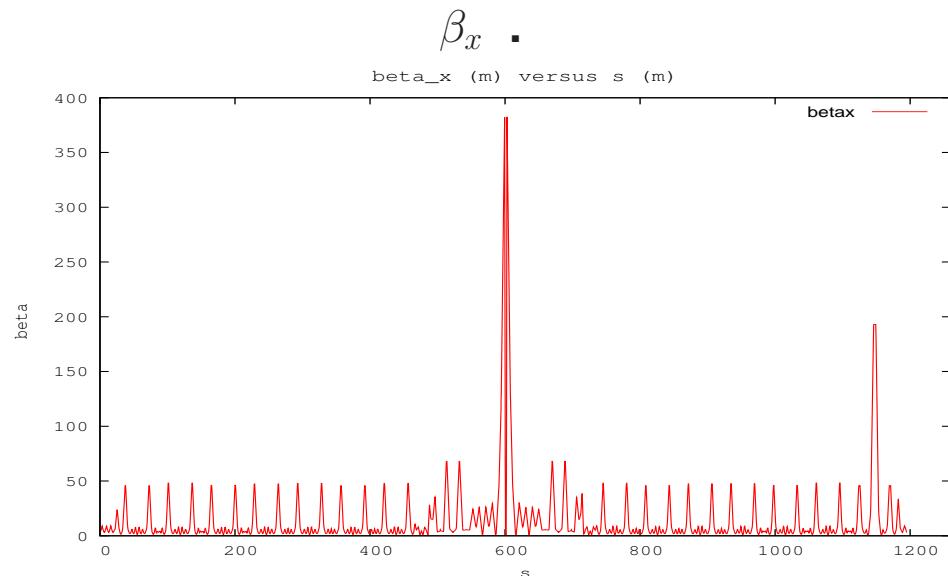
Abstract

this talk give an overview of the work I've done on spin dynamics last year, at LPSC
and at SLAC with U. Wienands.

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1 Orbital dynamics checks for V16 : tunes, DA, β s



Many more cross-checkings on orbital dynamics can be done.

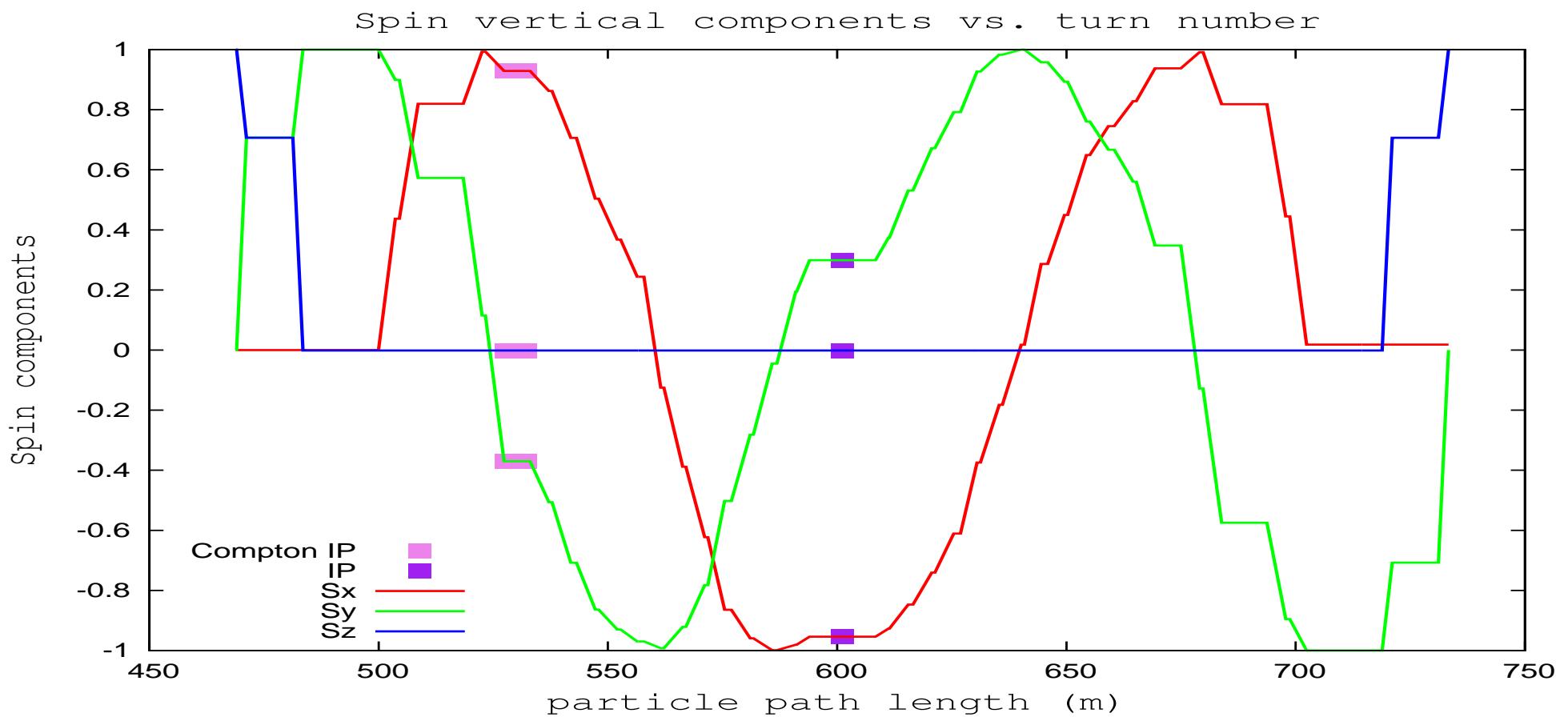
- FMA,
- Amplitude detuning,
- DAs,
- coupling,
- synchrotron radiation,

Zgoubi is a great code !

2 Invariant Spin Field : Definition and Goals

- **Invariant Spin Field** is a spin vector field such that if we track a particle with its spin initially aligned with it, the spin remain aligned along the field whatever the phase space position (without synchrotron radiation). It could be understand as the **local spin precession axis**.
- Once the **6D Invariant Spin Field** is computed, **Derbenev-Kondratenko** formula can be used to compute the expected **polarization** and **depolarization time**.
(we transport the ISF, computed for one point in the ring, along the whole ring)

3 First order spin checks. components : S_x longitudinal, S_y radial, S_z vertical(V16).



1 particle with vertical initial spin. Nominal Energy (4.18 GeV)

- n_0 axis is **not longitudinal at IP**.
- n_0 tilt at injection is better

The compton IP is located in a free field area close to an upstream 180° spin rotation (in drift DX0L, length 408cm).

4 Invariant Spin Field Methods : Stroboscopic vs. spectral.

Stroboscopic averaging

Developped by Hoffstaetter et al.

Based on averaging of spin coordinates.

+ Already used at DESY

+ Principle is simple

- Convergence is slow

$O(10^3)$ tracking turn per ISF point.

- Large CPU for 6D tracking

- tricky analysis code
deal with huge data set
hard to parallelize

+ Tool developpement is done.

Spectral

Principle by Yokoya

Based on fourier analysis of the spin motion.

- no intensive use (tested at desy)

- Numerical stability issues

+ Convergence is better

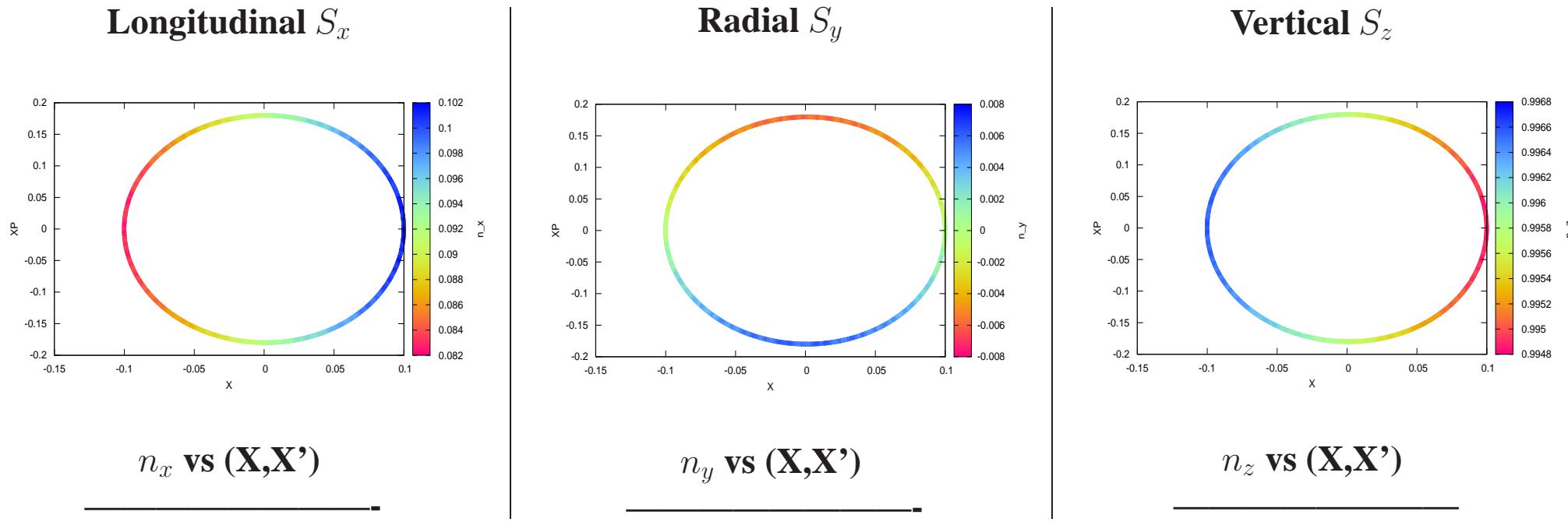
$O(1)$ tracking turn per ISF point.

+ Reasonable CPU for 6D tracking

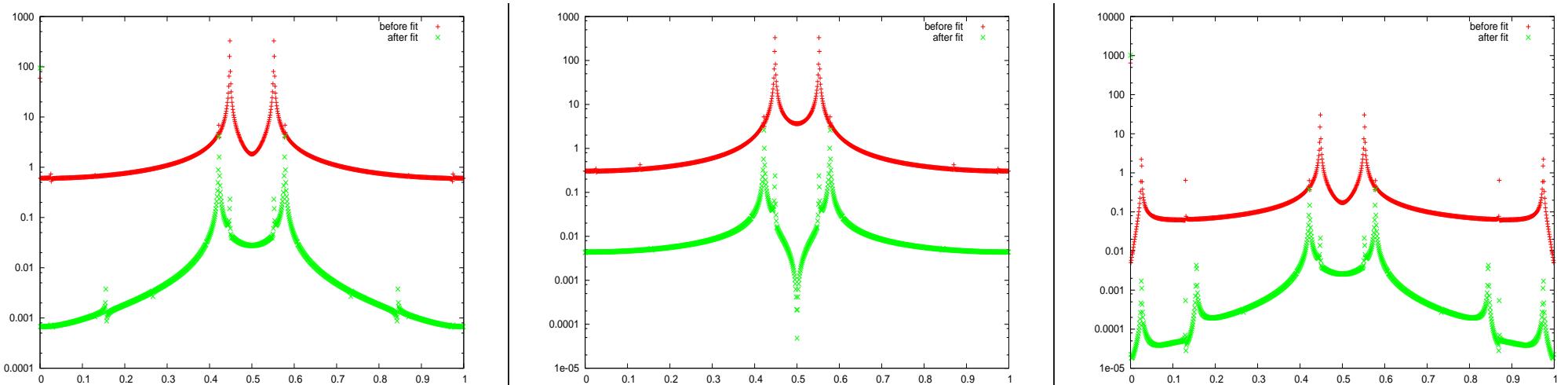
+ analysis code is much easier
easily parallelized
fast

- Tool is under developpement.

5 ISF : Preliminary results for the spectral method (V12).

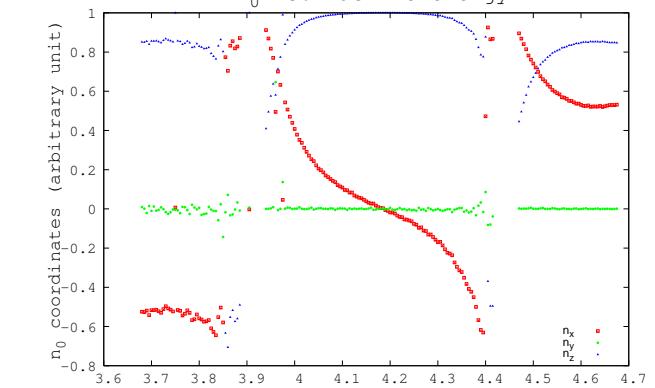
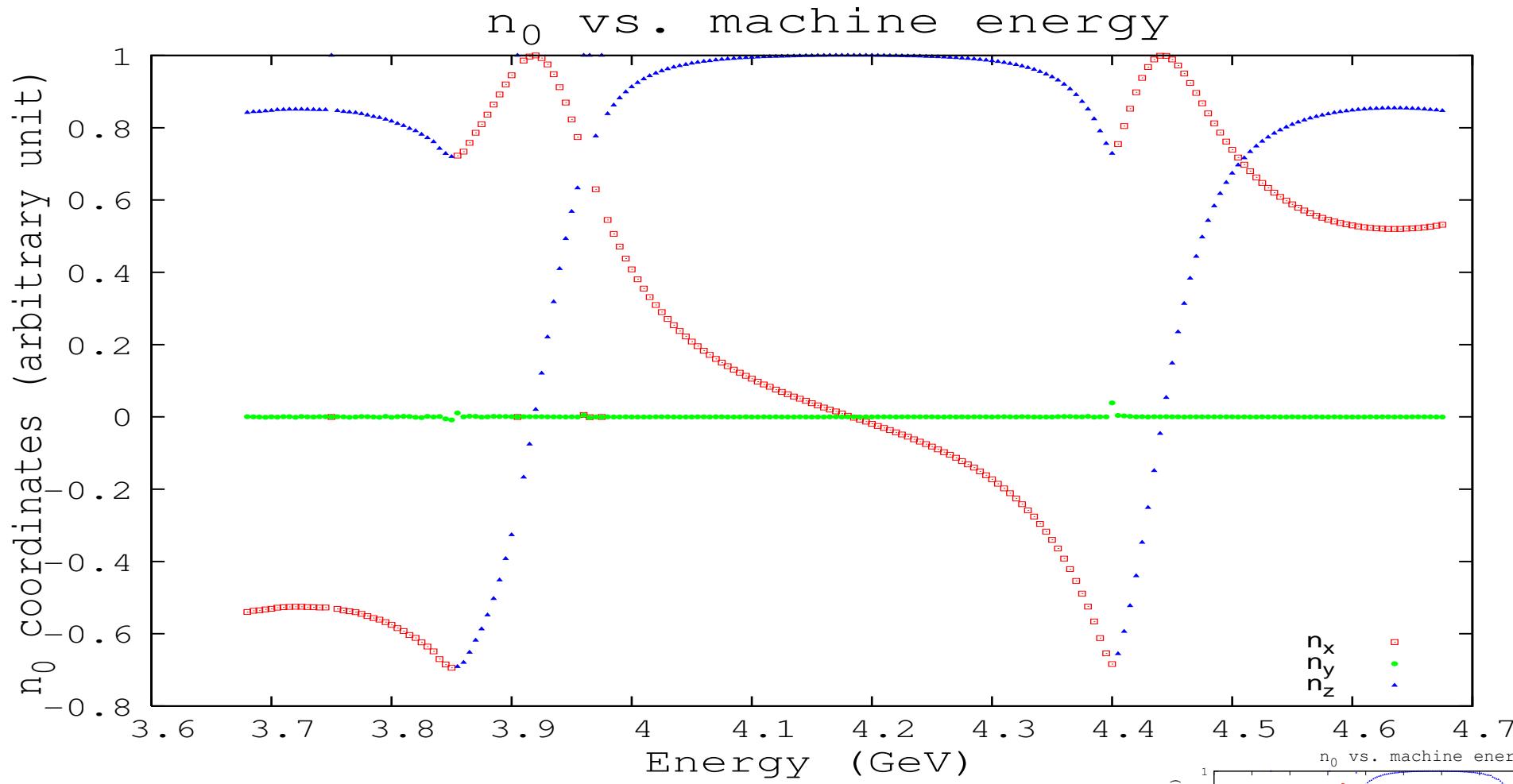


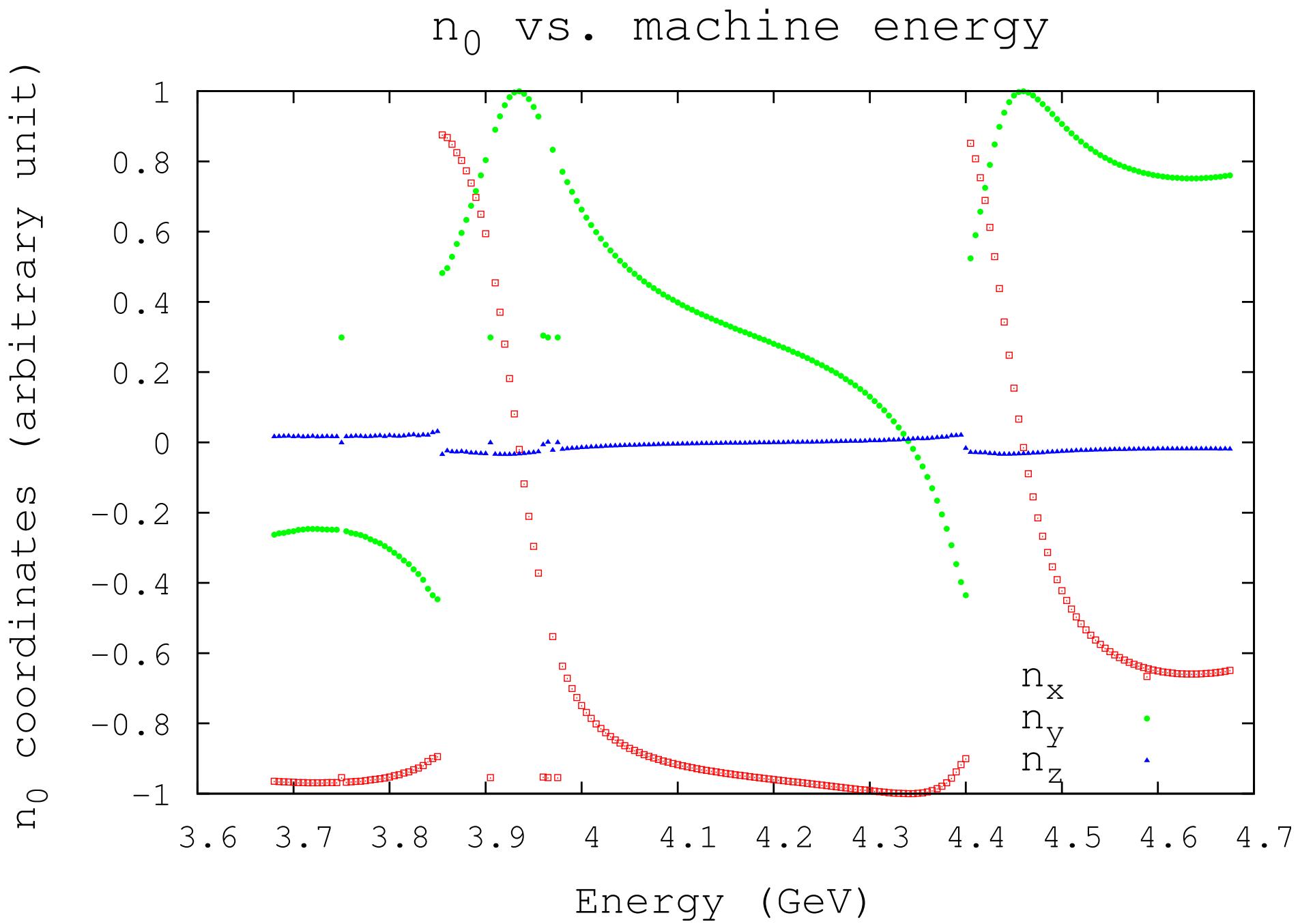
spectrum (FFT) of S_x , S_y and S_z . arbitrary initial direction, spin aligned with ISF.
2x1024 turn tracking, looking at injection point.



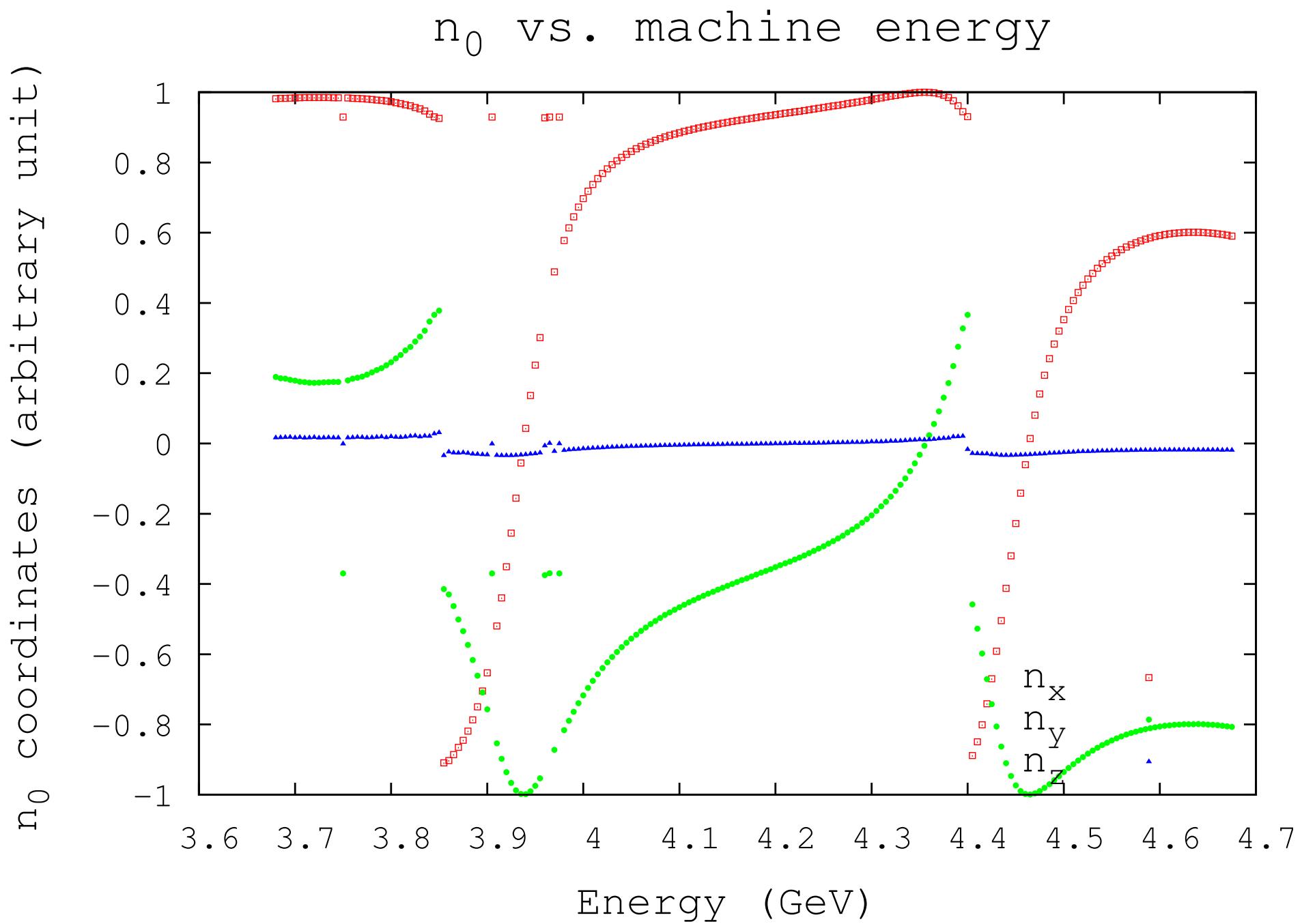
6 \vec{n}_0 at injection (V16)

Big is stroboscopic, small is spectral. spectral is noisy due to numerical issues mentionned.



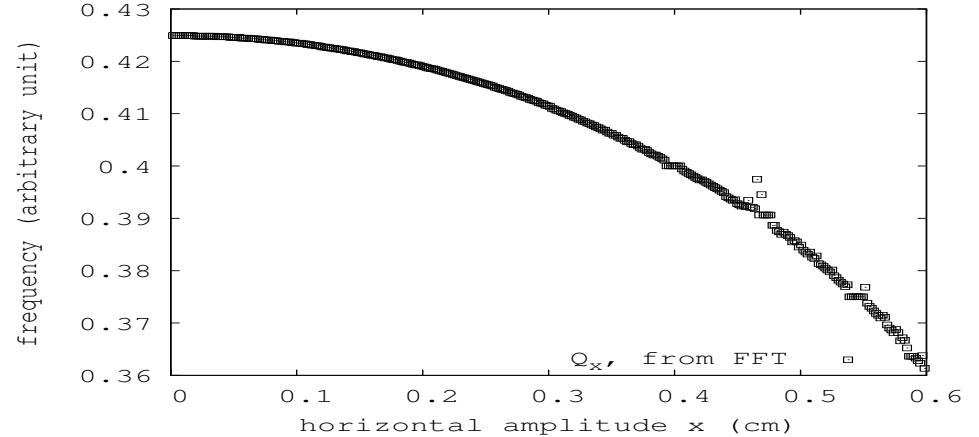
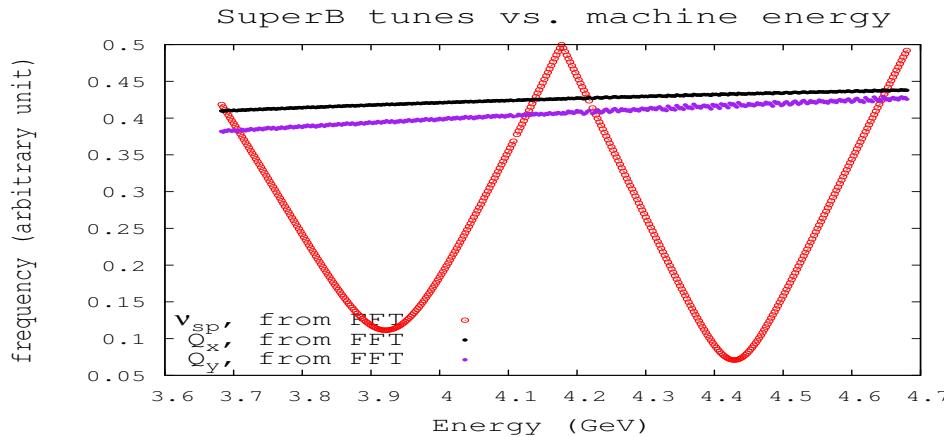
7 \vec{n}_0 at IP(V16)

8 \vec{n}_0 at Compton IP(V16)



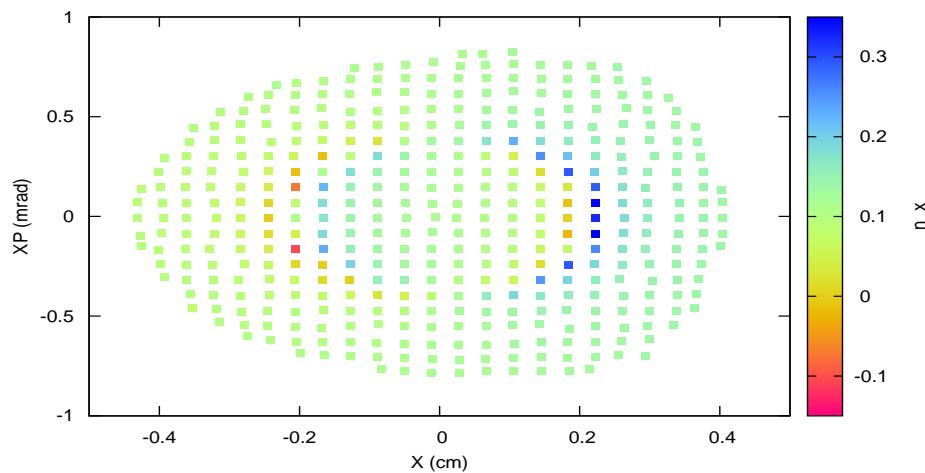
9 Amplitude induced resonances (V12).

Simulation for **V12 lattice**, rescaled at 4.13 GeV. As the principle is more general, we should encounter the same behaviour for V16...

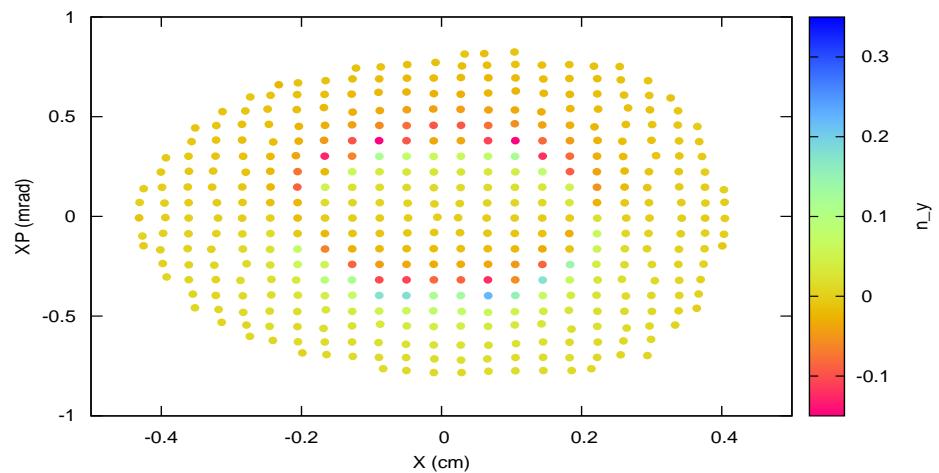


The amplitude of the motion changes the orbital tunes such that we cross a spin resonances :

$$k_1 \cdot \nu_{spin} + k_2 \cdot \nu_x + k_3 \cdot \nu_y = \text{integer}.$$

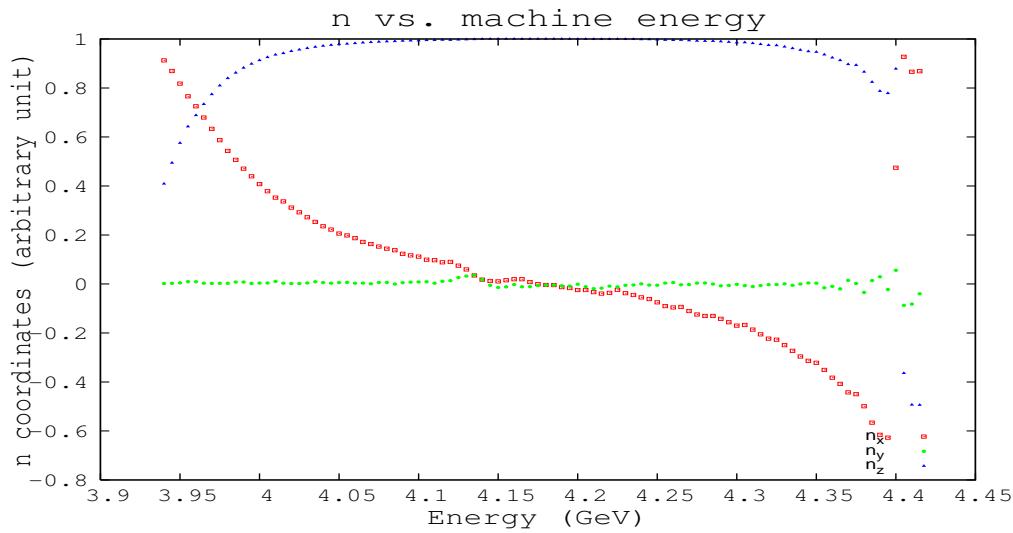


Longitudinal n_x



Radial n_y

10 : \vec{n} vs. $E_{machine}$ with vertical motion(V16)

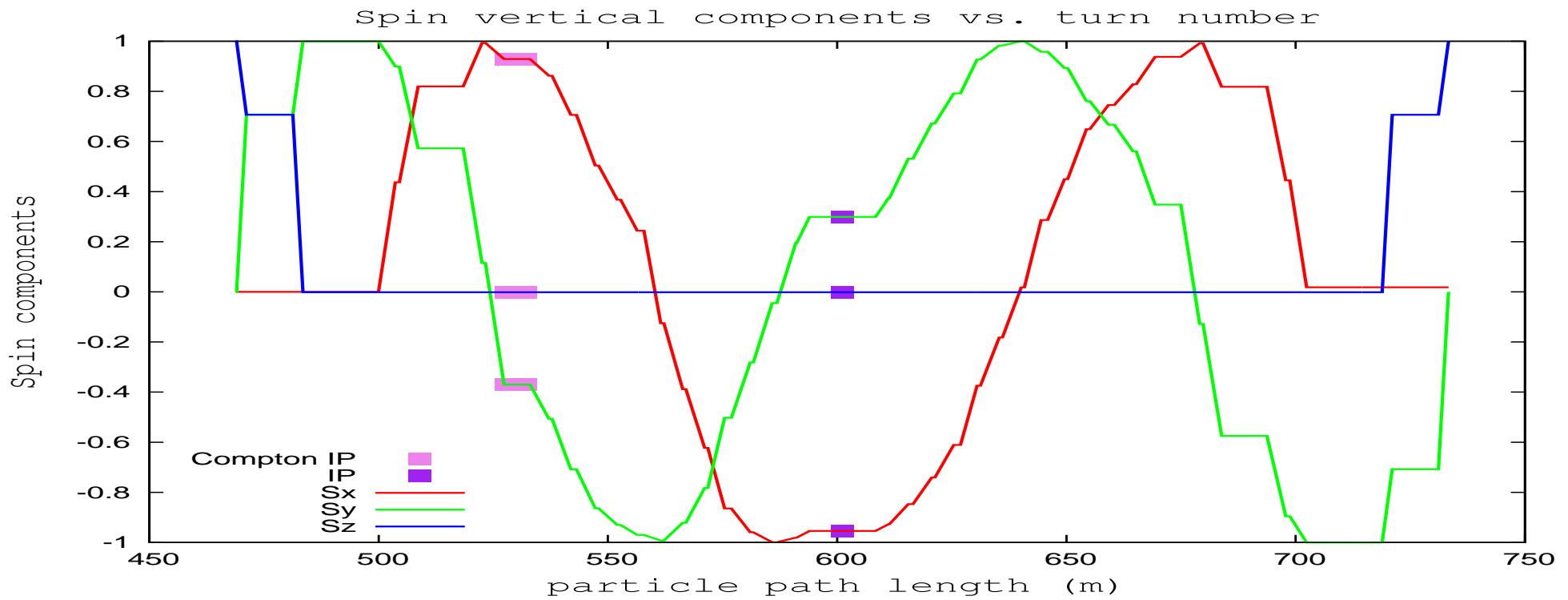


The animation for n vs $E_{machine}$ is coming ...

11 Conclusion : Achieved and foreseen work

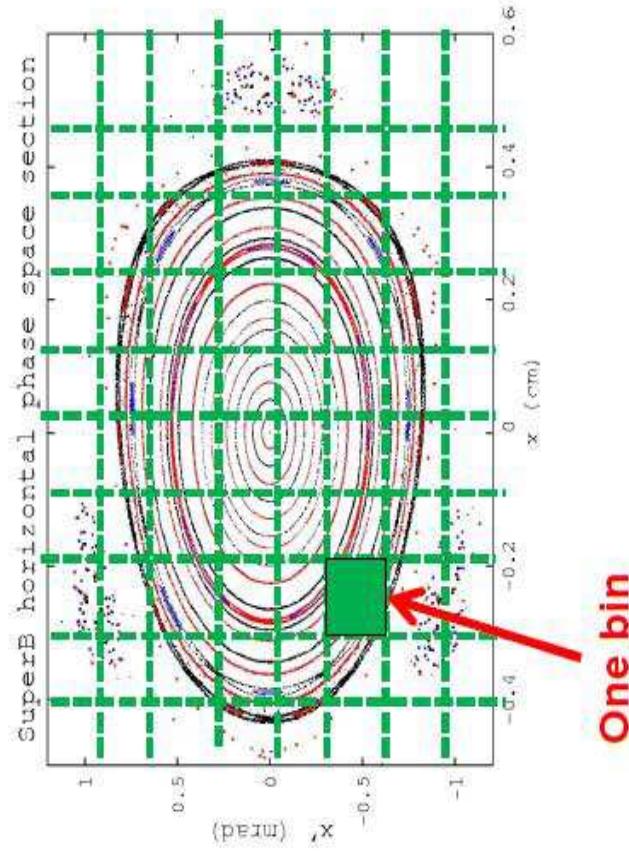
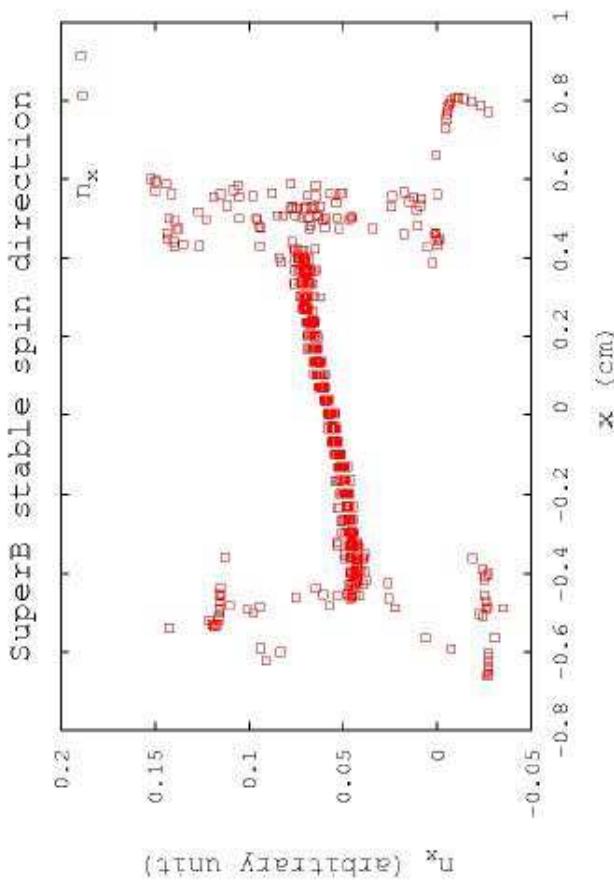
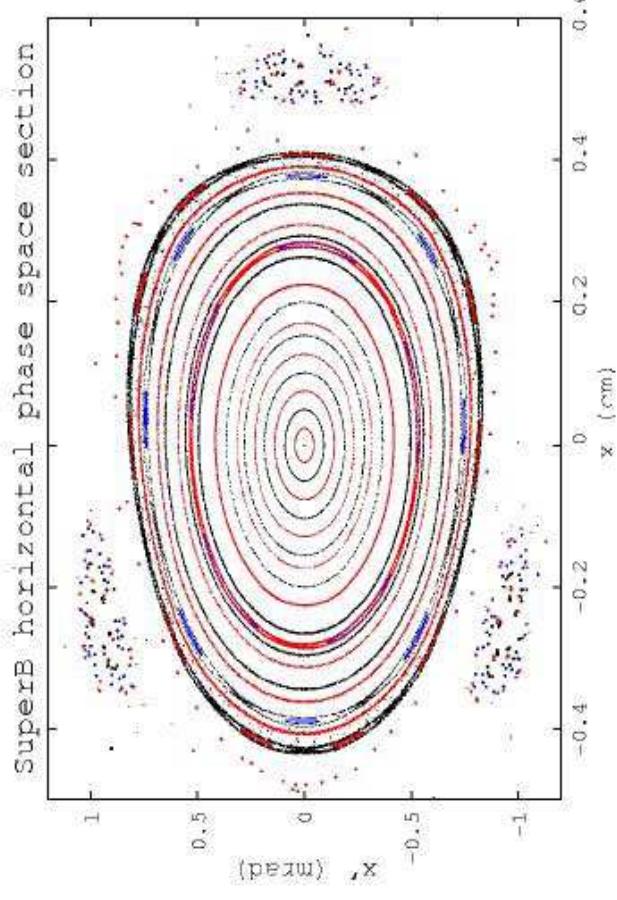
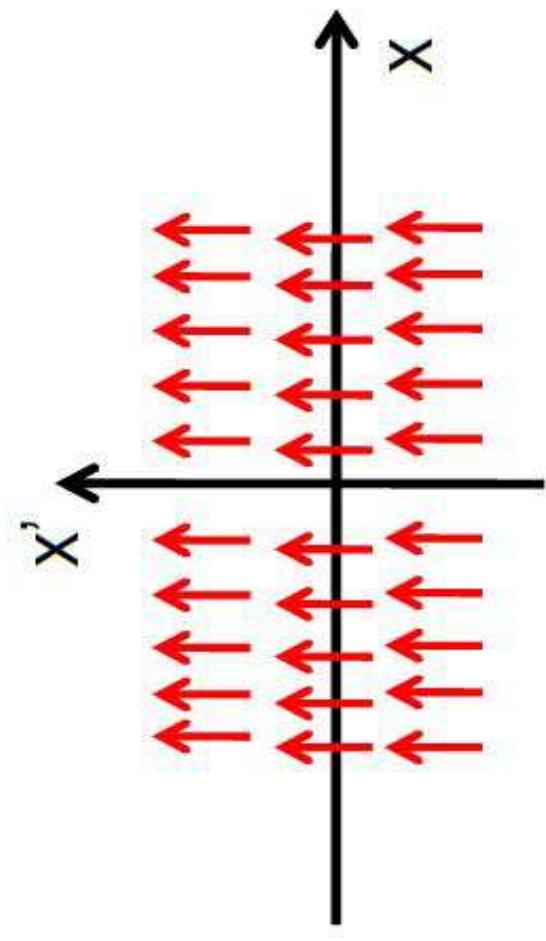
- Computing time is an issue.
 - Parallel calculation has been added and make computing time managable
@ccin2p3 : 10turn/min/core, ~ 80 cores available.
 - reduce and fasten tracking data output .
 - Optimize compilation (speed x2)
- 6D motion is working **
- Stroboscopic averaging method for full 6D motion is implemented. The tool is very well suited for 2D or 4D analysis, but computing time is still a problem for 6D.
- ADST from FFT (spin tune) has been implemented. Fourier analysis does work in most of the realistic case (tricky in some other case).
- Spectral approach for ISF has been implemented. We first did some approximations that make the implementation valid only in a restricted range, to make a first test. Improvements are being implemented, as it seems to be very efficient.
- ADST from Frequency Analysis will be (**) implemented for the spectral ISF approach.

** it's almost done, we did it yesterday morning with Simone
- 6D Compton IP ISF will soon be computed.
(Warning : it's not the bunch polarization, but it could help to understand what happen to spin there).
- DK Implementation, to compute expected polarisation.
- Go further in spin dynamics studies ! e.g. it seems very interesting to add a beam-beam element (weak-strong).



Thank you for your attention

Principle of stroboscopic averaging.



How it works (this is the principle, not the detailed implemented equations!) :

$$n_x(\vec{u}) = \sum_{i=0}^{N_{turn}} S_{x,i}(\vec{u}_i), \text{with } u_i \in bin_{6D}(\vec{u}) \quad (1)$$

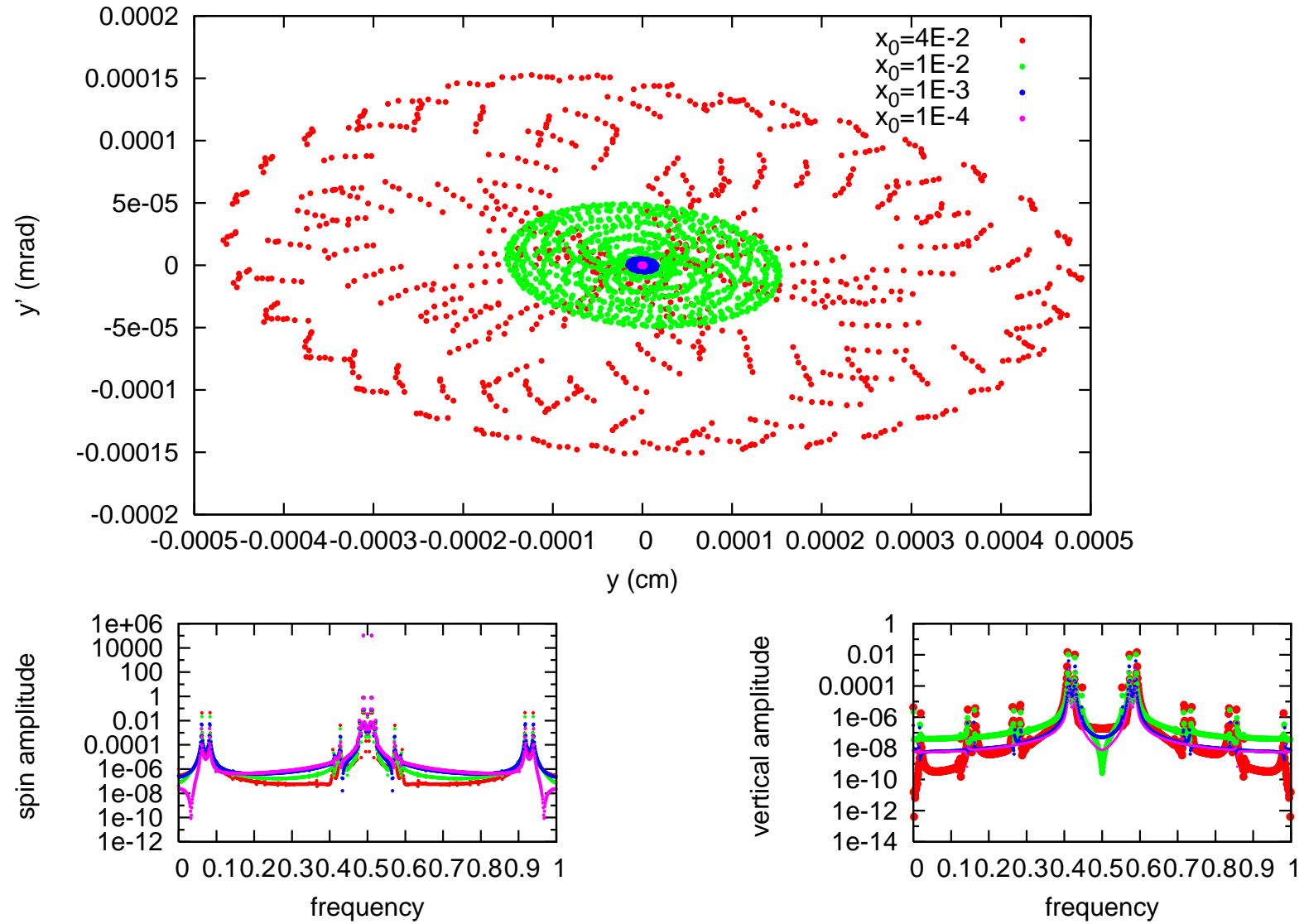
Or

$$n_x(\vec{u}_i) = S_{x,i} - (a_x \cdot \cos(2\pi\nu_{spin}t_i + \phi_x) + C_x) \vec{x} \quad (2)$$

where :

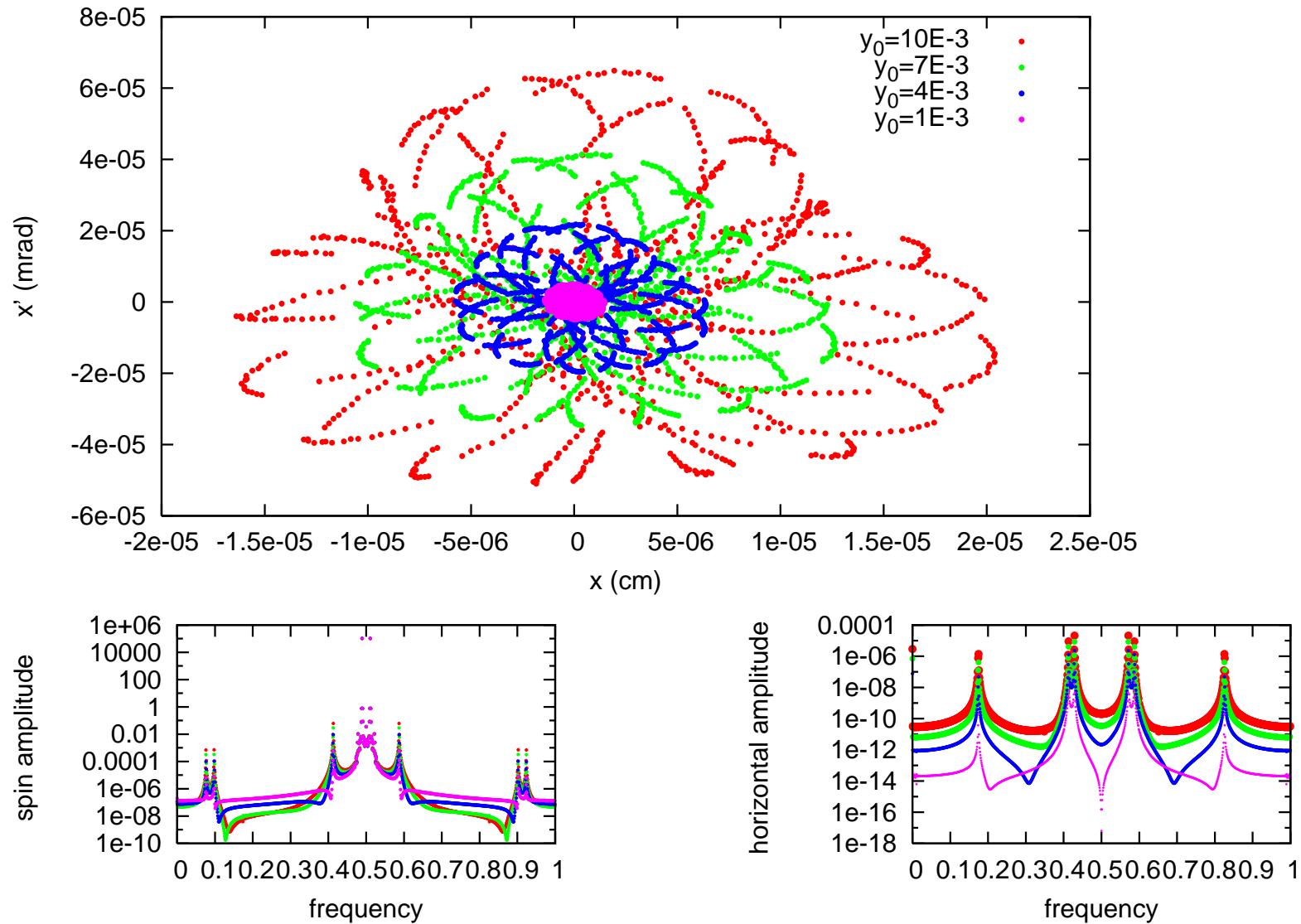
- **S_x is one of the spin components (in this case x is longitudinal),**
- **n_x is one of the invariant spin field components,**
- **$\vec{u} = (x, x', y, y', t, D)$ is the 6D particle coordinate vector**
- **a_x, C_x and ϕ_x are constants and ν_{spin} is the spin tune.**

Coupling x-y(V16)



This is an illustration, that will explain some difficulties we have with our spectral approach of Invariant Spin Field.

Coupling y-x(V16)



This is an illustration, that will explain some difficulties we have with our spectral approach of Invariant Spin Field.

Long term.

- Acceleration cavity & SR loss do work. After cross-check and verification on SR simulation, spin diffusion could be simulated if we manage with computing time.
- Remark : the DESY workshop on spin simulation tool pointed out an interest in coupling codes (e.g. coupling Zgoubi with GP++), but that's not realistic in terms of CPU.
- Implement Sokolov-Ternov effect.