LATTICE DESIGN TOOL DEVELOPMENTS REGARDING THE SUPER-B PROJECT

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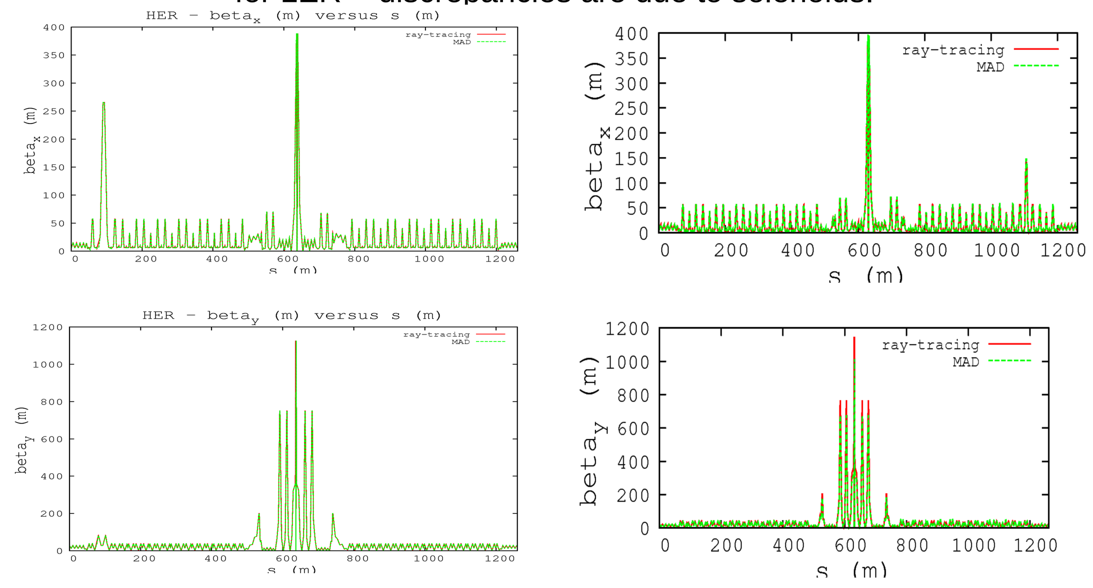
ABSTRACT

The assessment and qualification of the Super-B lattice parameters as produced by the on-going design studies require high precision dynamic simulations and ad hoc tools.
Preliminary investigations have been undertaken using the stepwise ray-tracing code Zgoubi, based on the numerical resolution of F = q v × B, thus allowing
(i) high precision magnetic fields modelling,
(ii) high precision particle and spin tracking ;
In addition, Zgoubi provides most of the tools relevant to detailed numerical of beam and spin dynamics in super-B high-energy (HER) and low-energy (LER) rings, such as spin tracking, synchrotron radiation, together with a number of optical elements and other dynamics numerical tools.

This poster reports on series of preliminary numerical simulations performed in the recent months, dedicated to,
(i) evaluating the code capabilities to study the super-B HER and LER lattices,
(ii) provide precision analysis of lattice behavior.

Optical functions

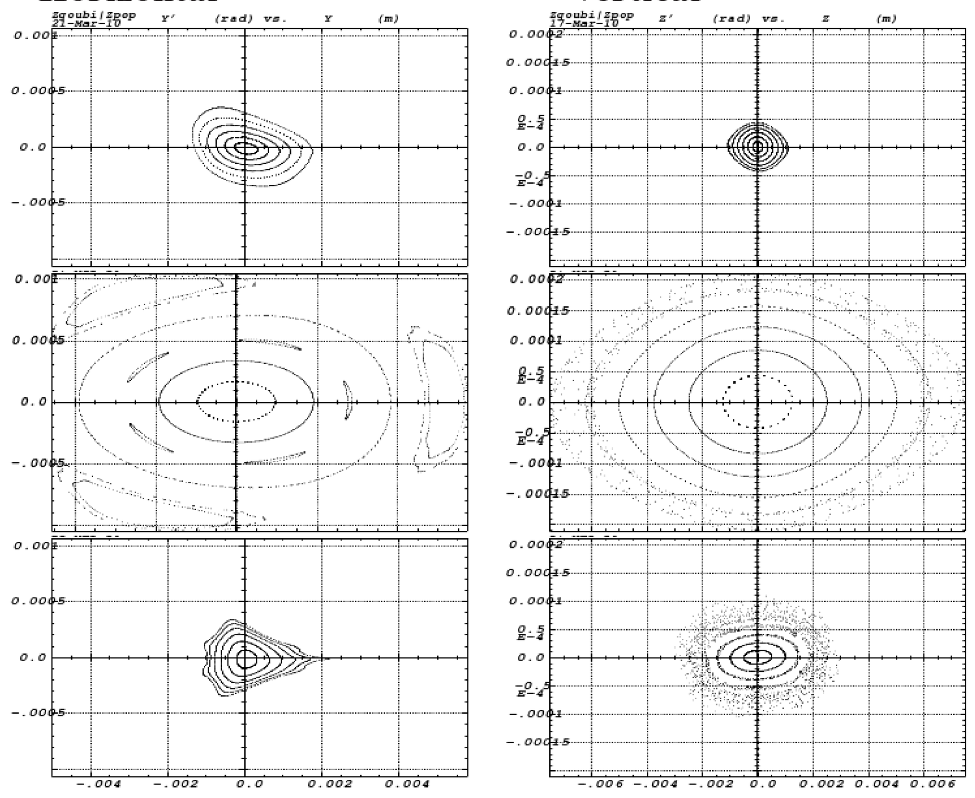
• MAD & raytracing are superimposed, agreement is excellent for HER, good for LER - discrepancies are due to solenoids.



Large amplitude motion

maximum stable amplitudes

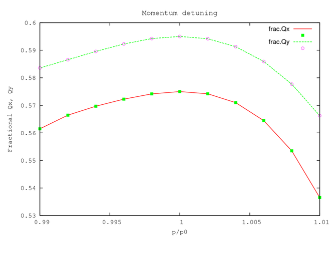
Horizontal **Vertical**



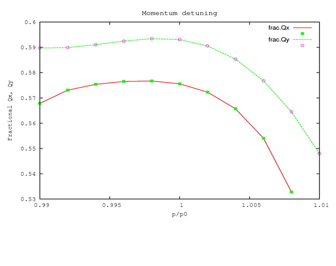
First order hypothesis

Comparing with MAD

	MAD8	Ray-tracing
HER		
Energy /GeV	6.7	
Orbit length /m	1258.3581	1258.3582
Q_x, Q_y	40.5750, 17.5950	[40].5750, [17].5950
Q'_x, Q'_y	0.042, -0.0038	0.062, -0.0019
α, $\sqrt{1/\alpha}$	$4.361\,10^{-4}$, 47.88	$4.371\,10^{-4}$, 47.83
Max β_x, β_y /m	388.57, 1126.40	388.55, 1126.35
Max Dx /m	0.6346	0.6346
LER		
Energy /GeV	4.18	
Orbit length /m	1258.3581	1258.3582
Q_x, Q_y	42.5744, 18.6019	[42].5749, [18].5949
Q'_x, Q'_y	-0.620, -0.678	-0.624, -0.676
α, $\sqrt{1/\alpha}$	$4.049\,10^{-4}$, 49.69	$4.053\,10^{-4}$, 49.67
Max β_x, β_y /m	396.54, 1013.17	387.25, 1146.77
Max Dx /m	0.5118	0.5118

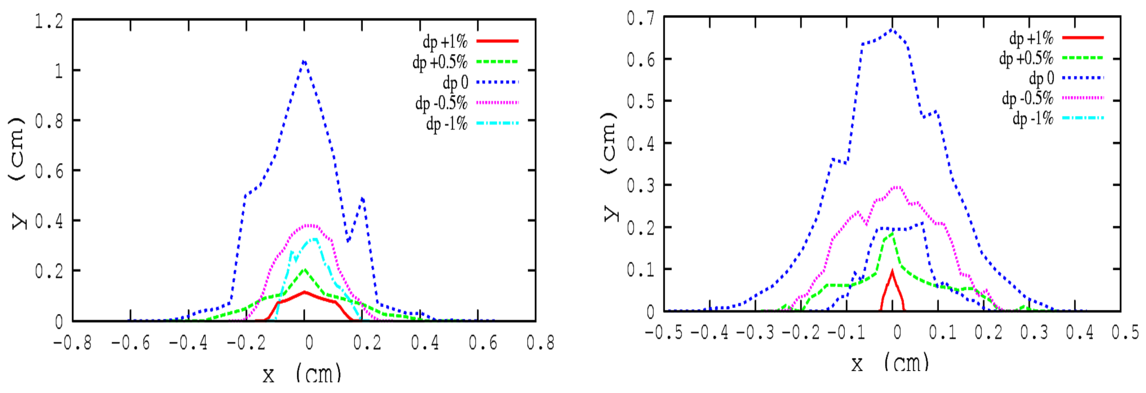


Momentum detuning, Top HER, bottom LER



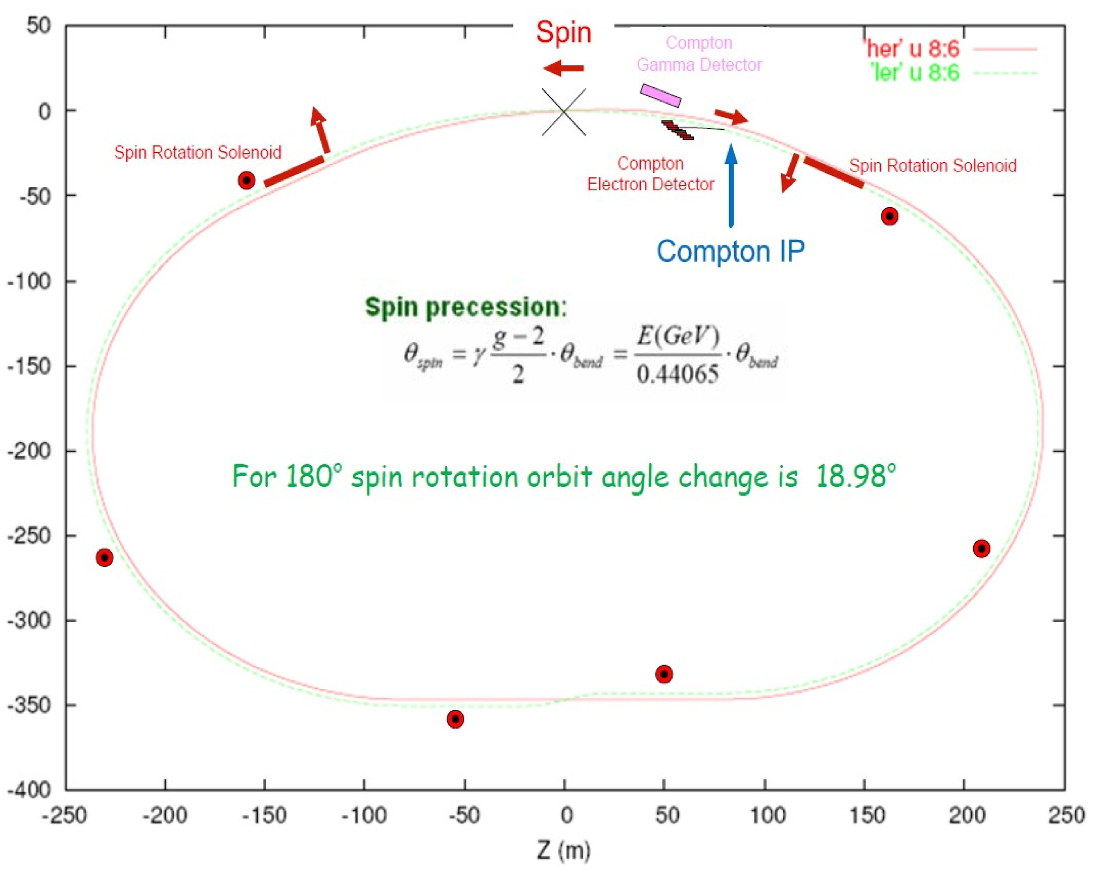
Dynamic Apertures

HER LER



Layout of spin related elements

Interaction Region

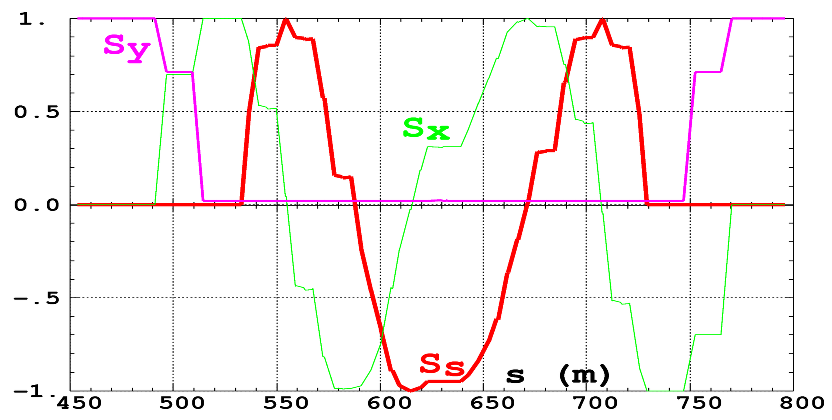


Spin motion

$$\frac{d\vec{S}}{dt} = \frac{-e}{m\gamma}\left[(1+\gamma a)\vec{B}_T + (1+a)\vec{B}_L\right] \times \vec{S}$$

Thomas-BMT equation for spin motion is solved simultaneously with particle motion, if requested. In LER, the spin vector of the electron beam has to be longitudinal at the interaction point. This is ensured via a rotator comprised of two sets of four solenoids, located on both sides of the interaction region (IR). One can find the n0 (s) spin vector on closed orbit using the built-in fitting procedure in Zgoubi, while imposing identical spin coordinates after one turn. As n0 (s) is vertical in the arcs at appropriate momentum, this method can be used to adjust the rotator and IR bends in order to reach longitudinal polarization at IP.

Spin tracking simulations

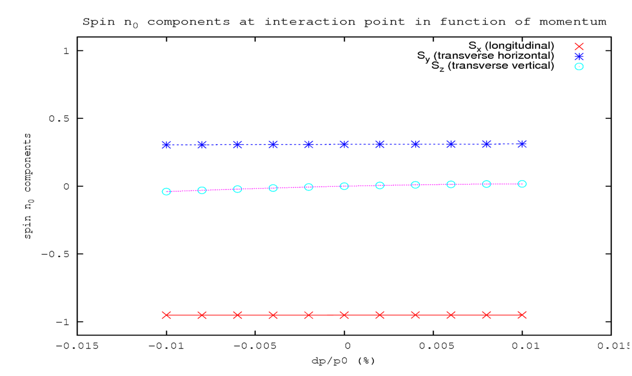


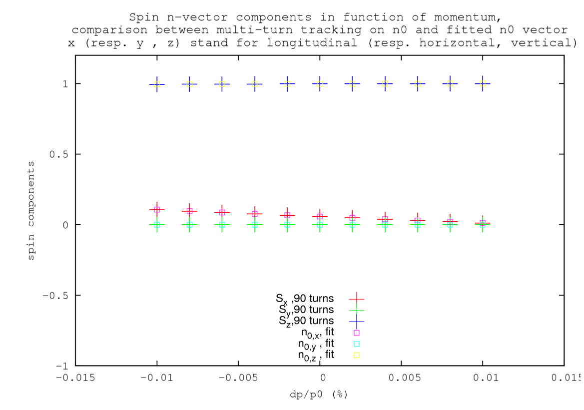
Top : Spin components in interaction region

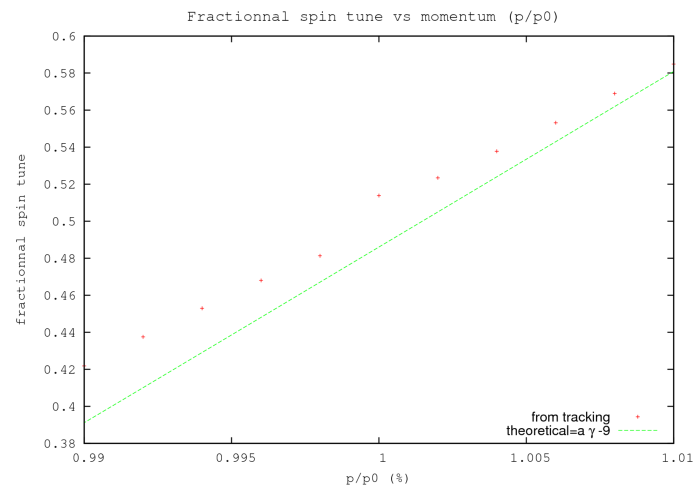
Middle left : spin components in function of momentum, in RF section

Middle right : spin components in function of momentum, in IR, comparison between fit and multiturn.

Bottom : Spin tune, comparison with theoretical prediction







Spin tune is computed from 1-turn tracking data for particles on closed orbit, for different momenta ; injected particles have radial outward spin, and we extract the angle between projections, in the plane of precession, of spin vectors, injected and after one turn.

Multiturn tracking, SR and RF ON

RF allows recovering synchrotron radiation (SR) induced energy loss.

Stochastic synchrotron radiation and its effects on particle dynamics are simulated in a very regular manner, as follows.

Number of photons, k, emitted in a step : $p(k) = \lambda^{-k}\ \exp(-k)\ /\ k!$

Cumulative distribution of the energy probability law : $\mathcal{P}(\epsilon/\epsilon_c) = \frac{3}{5\pi}\int_0^{\epsilon/\epsilon_c}\int_{\epsilon/\epsilon_c}^{\infty} K_{5/3}(x)dx$

REMINDER :

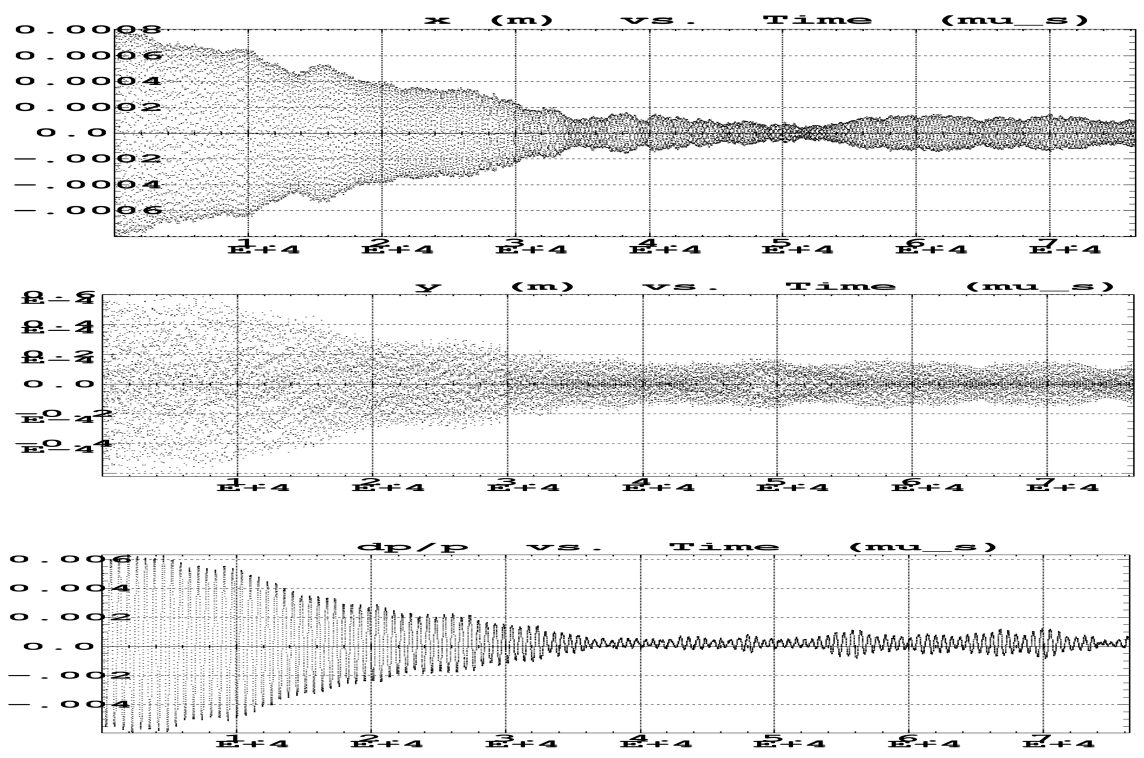
Let $e_i[keV] = 88.5E^4[GeV]\,\alpha_i/2\pi$ be the energy loss in dipole i (of N in the ring) characterized by its deviation α_i with local radius ρ_i, and $\epsilon_i = 0.683E^3[GeV]/\rho_i[m]$ the average photon energy, then, energy loss per particle $E_{loss}[keV] = \sum_i^N e_i$, a sum over the N dipoles ; number of photons per particle, $N_{phot} = \sum_i^N e_i/\epsilon_i$; beam $\sigma_E/E = \gamma\sqrt{C_q/2\rho}$ with $C_q = 55\hbar/32\sqrt{3}m_0c \approx 3.84\,10^{-13}$; damping time $\tau_E[turns] = E_s/E_{loss}$, $\tau_E[ms] = 4.2\,10^{-3}E_s/E_{loss}$.

Theoretical parameters entering SR simulations in LER

Synchronous energy E_s	GeV	4.18
Orbit length	m	1258
Revolution time	μs	4.20
Average energy loss /particle/turn, E_{loss}	keV	865
Equivalent ρ, $88.5E_s^4[GeV]/E_{loss}[keV]$	m	31.2
$\hat{V}\sin(\phi_s)$	kV	865.13

SR in LER, comparing theoretical and Monte Carlo

		theoretical	Zgoubi
E_{loss}	keV	865.1	878.4
N_{phot}		541.4	541.3
ϵ_x/π		$1.8\,10^{-9}$	$1.4\,10^{-9}$ $^{(a)}$
τ_x	ms		≈ 28 $^{(b,a)}$
σ_E/E		$0.67\,10^{-3}$	$0.68\,10^{-3}$ $^{(c)}$
τ_E	ms	20.3	≈ 15 $^{(b,c)}$



CONCLUSIONS

The raytracing method proposed by Zgoubi provides acurate beam simulations as demonstrated by comparisons with theory and other codes. As such, Zgoubi can be an efficient and useful tool to study beam and spin dynamics as well as SR aspects in the Super-B lattice.

It is foreseen to explore further analysis methods as frequency map techniques, based on Zgoubi outputs.

Sokholov-Ternov effect will be implemented and further studies regarding spin diffusion will be performed.

Other studies as invariant Spin Field issues, implementation of beam-beam effects, are being considered.

Field modeling

Fields are derived from scalar potentials.

Dipoles and quadrupoles, w or w/o fringe fields :

$$V_n(s,x,y) = (n!)^2\Big\{\sum_{q=0}^{\infty}(-)^q\frac{\alpha_{n,0}^{(2q)}(s)}{4^q q!(n+q)!}(x^2+y^2)^q\Big\}\Big\{\sum_{m=0}^{n}\frac{sin(m\frac{\pi}{2})x^{n-m}y^m}{m!(n-m)!}\Big\}$$

Solenoids :

$$s/\sqrt{s^2+r^2}\ +\ (L-s)/\sqrt{(L-s)^2+r^2}$$

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