Implementation and study of depolarizing effects in GUINEA-PIG++ beam-beam interaction simulation

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Implementation and study of depolarizing effects in GUINEA-PIG++ beam-beam interaction simulation

- Depolarization effect overview
- Depolarization & beam-beam simulations
- GP++/CAIN Comparison for beam state after interaction
- GP++/CAIN Comparison at the luminosity contribution time

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Depolarization

• Spin Precession induced by the collective EM field of the oncoming beam, described by T-BMT equation (dominant effect at ILC):

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

Where a=0.0011596 is the coeff of anomalous magnetic moment of electron

Precession angle = γa x deflection angle ➔ 567xdeflection angle for ILC nominal

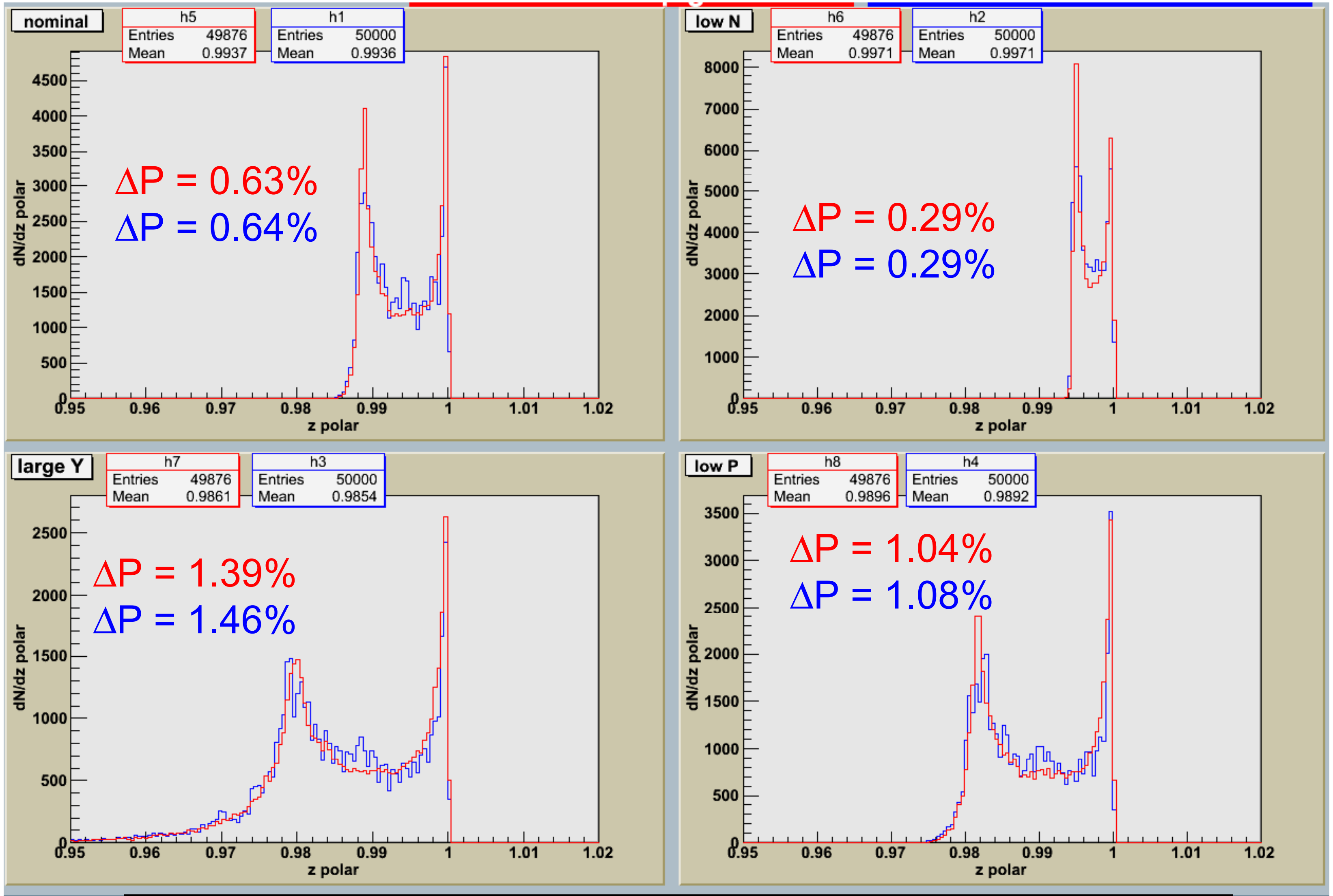
• Spin-Flip effect during synchrotron radiation: Sokolov-Ternov effect, tends to depolarize spins in linear collider. Probability for the spin to flip (s➔-s) at the moment of photon emission, proportional to the photon energy.

• At very hight energy ST effect becomes more important

Depolarization & beam-beam simulations

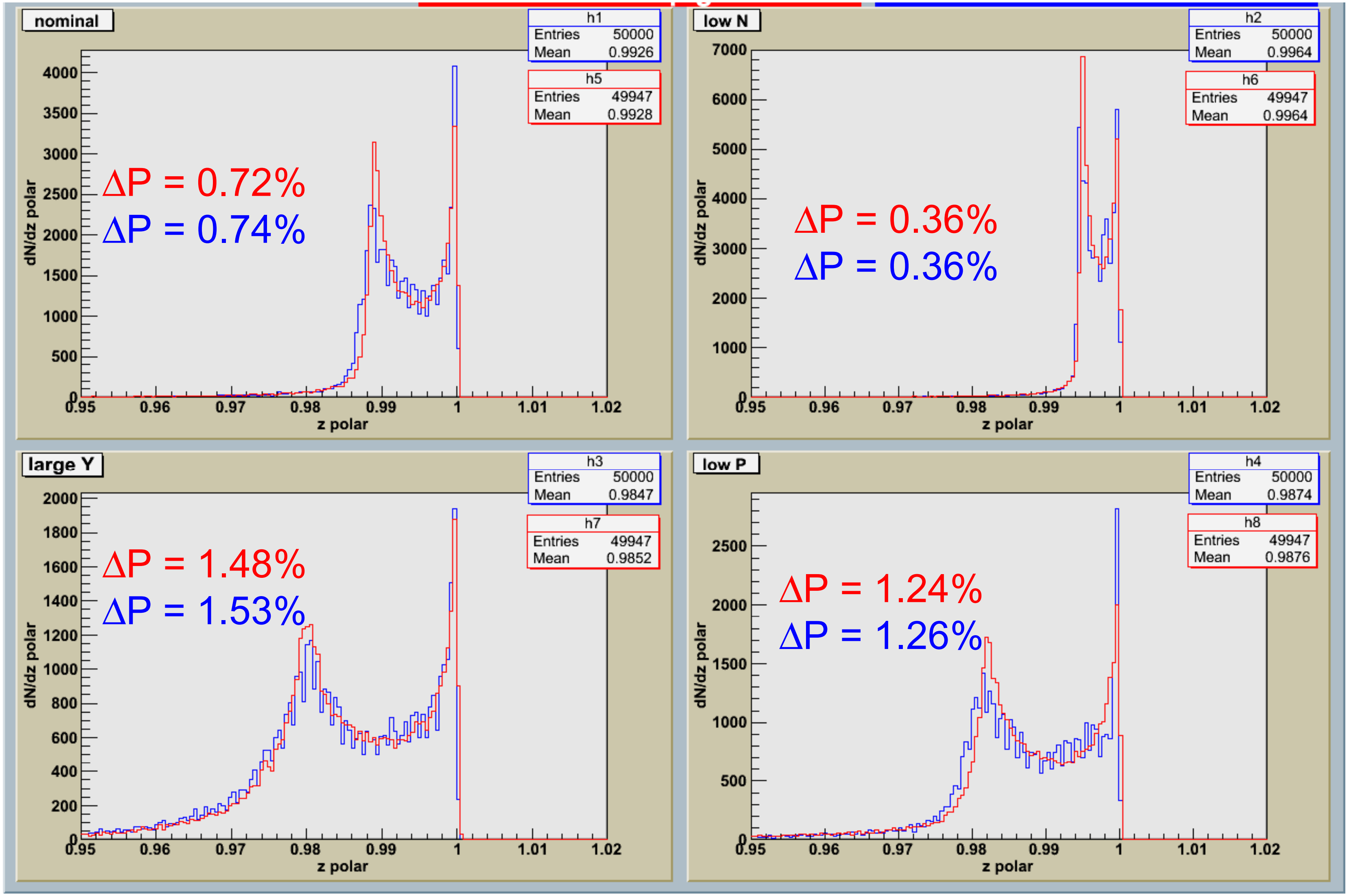
- In beam-beam simulation, particles are replaced by macro-particles → statistical representation.
- In GP++, access to the state of the interacting particles in the luminosity file.
- In Cain, luminosity file contains luminosity values as function of energy bins for all the polarization couples
- At a first implementation, Yokoya's formulae are used for ST process in GP++.
- Depolarization comparison between GP++ and CAIN can be direct for beam, not so direct for luminosity.
- For the moment: only beam particles have a spin treatment in GP++, CAIN as a more complete one (photons, pairs...)
- GP++ and CAIN works with totally or partially initial polarized beams
- Comparisons are shown for the 4 ILC beam parameter sets at 500GeV cms (Nominal, lowN, largeY, lowP) with 100% polarized beams

Comparison of GP++ & CAIN T-BMT depolarization for e^- beam after interaction: ΔP = 1 -<P>



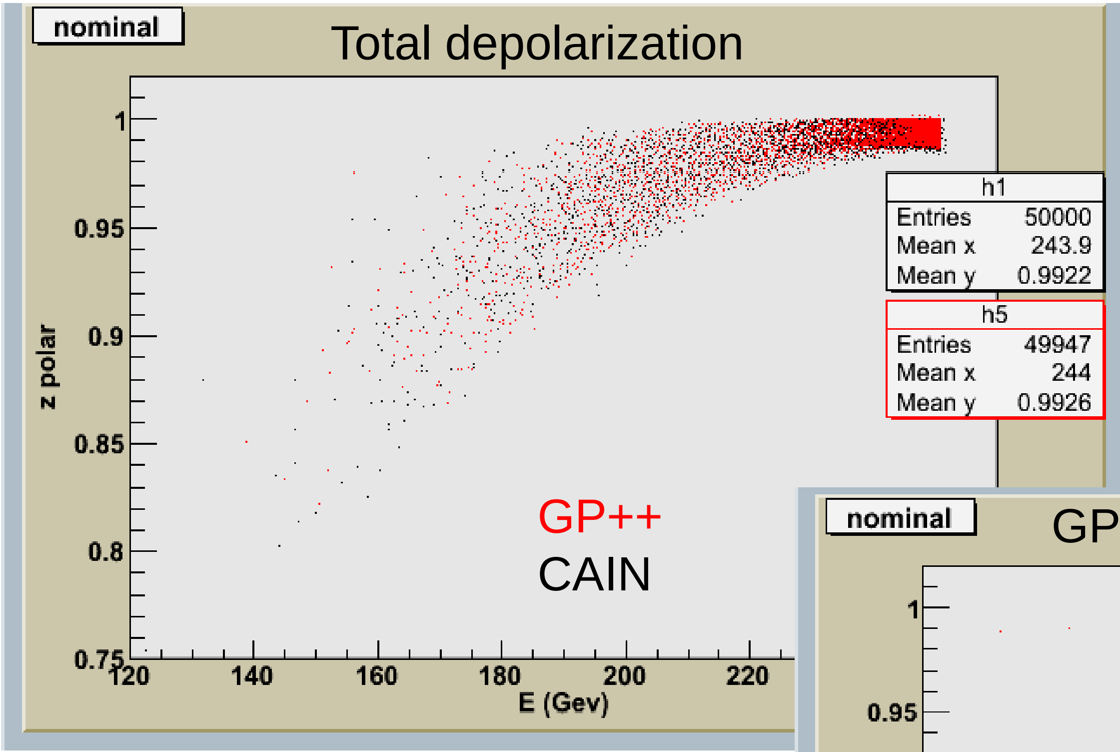
	Nominal	LowN	LargeY	LowP
(GP-CAIN)/CAIN (%)	-1.56	~0	-4.79	-3.70

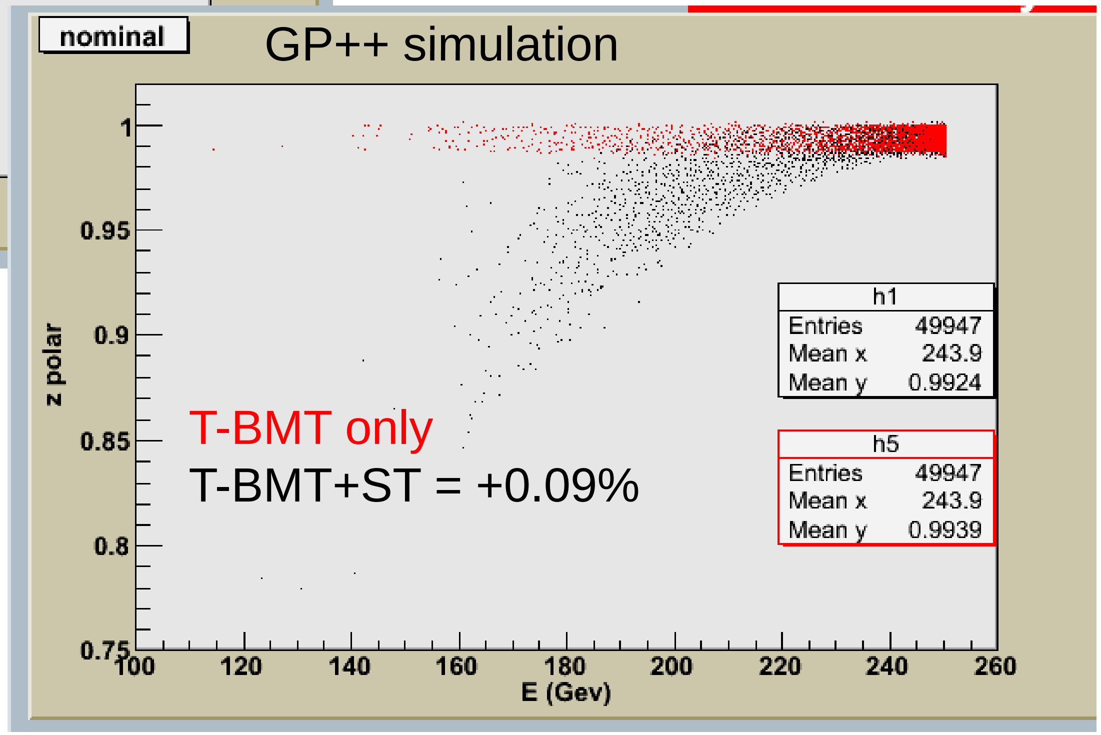
Comparison of GP++ & CAIN total depolarization for e^- beam after interaction: $\Delta P = 1 - \langle P \rangle$



	Nominal	LowN	LargeY	LowP
(GP-CAIN)/CAIN (%)	-2.70	~0	-3.27	-1.59

Look on depolarization energy dependence





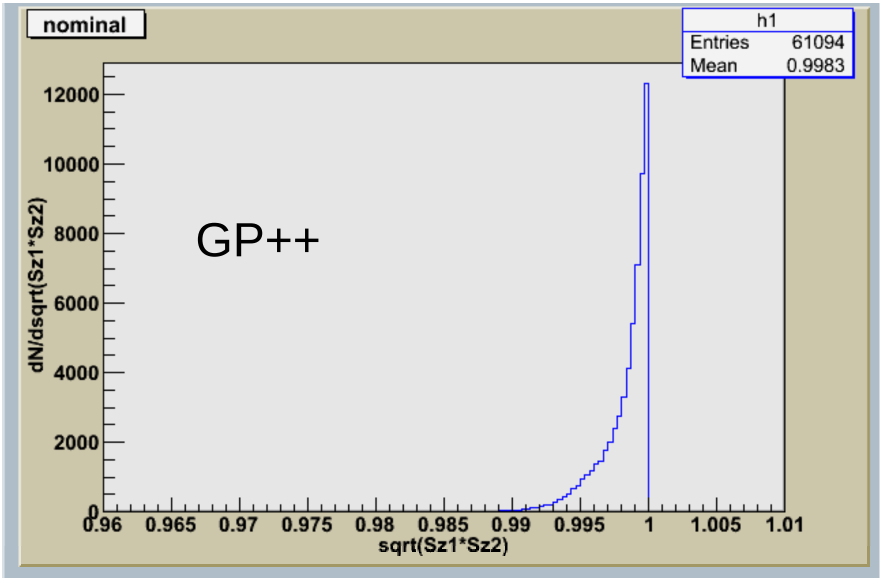
ST depolarization is prop. to beamstrahlung amount.

Luminosity weighted depolarization

= particle polarisation states at effective e^-e^+ interactions

- From Yokoya & Chen paper, ΔP_{lw} ~0.273ΔP for T-BMT process

- With GP++, access to individual polarization state of the luminosity contributing particles, at the interaction event.
We calculate $\Delta P_{lw} = 1 - \mathrm{sqrt}(\langle Sz1 * Sz2 \rangle)$,
Sz beeing the statistical normalized population polarized +1 per macro-particles



- For CAIN, access to luminosity values for different couple of polarisation states.
We calculate $\Delta P_{lw} = 1 - \mathrm{sqrt}(L_{zz}/L_{tot})$, L_{zz} being the luminosity for events polarized ++

Luminosity weighted depolarization

Lumi Depolarization in **GP++**	Nominal	LowN	LargeY	LowP
T-BMT only (%)	0.17	0.08	0.41	0.28
T-BMT+spin-flip (%)	**0.23±0.01**	**0.13±0.01**	**0.46±0.01**	**0.41±0.01**
$\Delta P_{lw}/\Delta P$ for T-BMT	0.270	0.276	0.295	0.269

Lumi Depolarization in **CAIN**	Nominal	LowN	LargeY	LowP
T-BMT only (%)	0.19	0.09	0.48	0.30
T-BMT+spin-flip (%)	**0.24**	**0.13**	**0.57**	**0.50**
$\Delta P_{lw}/\Delta P$ for T-BMT	0.297	0.310	0.329	0.278

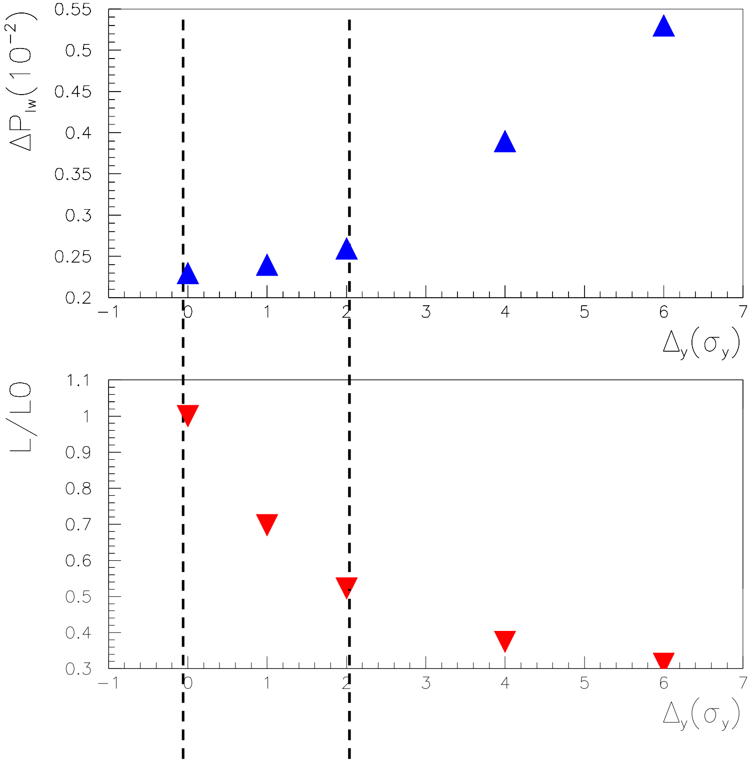
(SpinFlip)/tot (%) *withGP++*	26	38	11	32

(GP-CAIN)/CAIN (%)	-4	~0	-19	-18

- Problem with LargeY and LowP (20% diff CAIN/GP)?
- SpinFlip represents about 10 to 40% of the total depolarisation

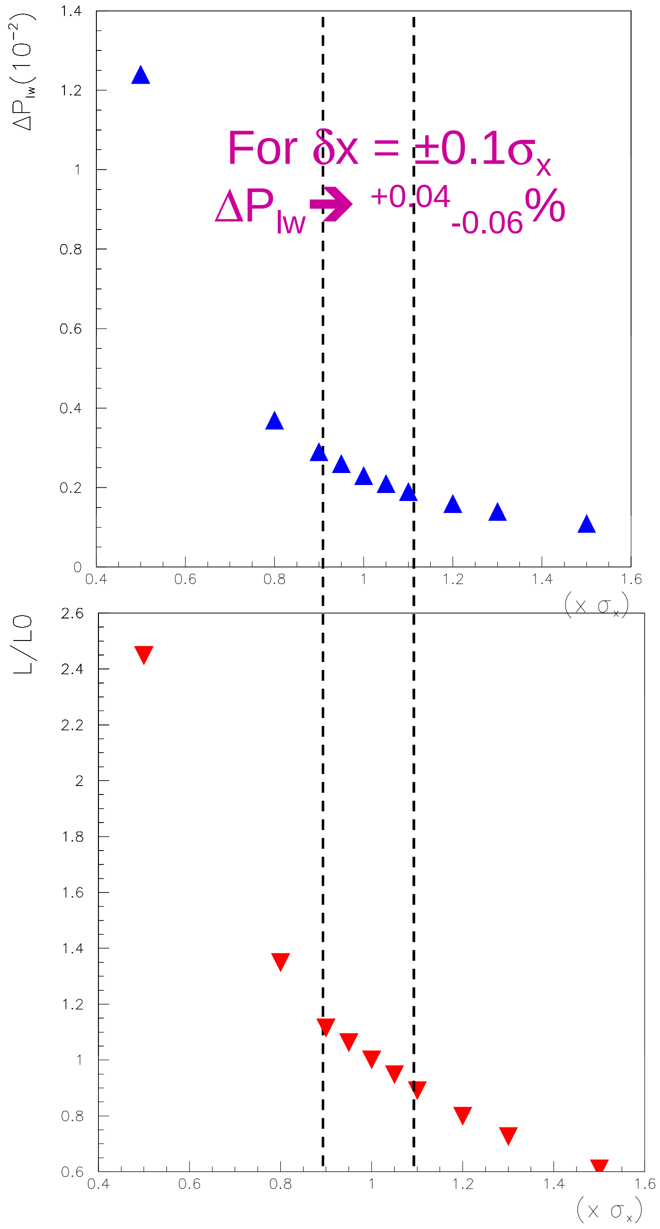
ΔP_{lw} sensitivity to beam errors

- No dependence with beam offsets, Δ_x, Δ_y, within realistic luminosity range.



For $\Delta y = 2\sigma_y$
ΔP_{lw} ➔ + 0.03%

- No dependence with σ_y (testing within ±50%)
- Variation with σ_x.!



Depolarization in GP++: summary & future

- Comparisons with CAIN, the first reference, is the only way to test of GP++ depolarization simulation: Good agreement for basic cases.

- At Nominal case of the ILC total ΔP_{lw}~0.23±0.01 %

- Depolarization is sensitive to horizontal beam size variations: uncertainty of 10% on beamsize ➔ uncertainty larger than 20% on depolarisation.

- Partial polarization in GP++ has to be tested too (You are welcome)

- Theorical initial calculations should be verified and understood

- Photon depolarization will come later.

- More studies are needed for CLIC energy

We thanks I. Bailey, A. Hartin, K. Mönig, G. Moortgaat-Pick, D. Schulte for help and useful discussions