Physics implications of the proposed baseline

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- Physics impact from LHC results
- Physics issues at 250 position
- Conclusions

Just at the start of LHC …

- **ILC decision foreseen to be close after first interpreted LHC results**
  - Impact of possible LHC outcome should be incorporated in design discussions
- **Hints for Higgs or new physics scenarios**
  - Currently only based on fits of electroweak precision observables
- ***Personal remark: flexibility needed for ILC design …. difficult wrt cost estimates***
  - ***what might be the LHC outcome?***

Workshop LHC2FC@CERN 2/09

Questions from early LHC data (~10 fb^{-1})

- **Three cases studied:**
  - **LHC not detected anything**
  - **LHC only detected SM-like Higgs**
  - **LHC detected some new physics**
- **What could the LC do**
  - **in first ILC stage of 90 up to 500 GeV?**
  - **in LC upgrades?**
  - **in multi-TeV CLIC option?**

Input from (early) LHC possible?

On possible design features:

- **energy scale(s) of a LC**
- **running scenarios (when GigaZ? # of steps in scans?)**
- **e^+ polarization degree (45% ,60%,?)**
- **options (e^-g, gg, e^-e^-,high lumi GigaZ)**
- **detector concepts ?**
  - **impact on physics? On # of lumi data? $b\bar{b}$,$c\bar{c}$?..**

Nothing found at (early) LHC

- **Interpretation for ILC?**
  - **‘Top’ physics**
  - **indirect searches in $b\bar{b}$, $c\bar{c}$, $l\,\bar{l}$ (large ED, CI)**
  - **ew precision runs from Z-pole data**
- **But is then really 500 GeV as first ILC stage needed?**
  - **or better 350 GeV? High-lumi Z-factory?**

Why 'top' physics?

- **Current average:** m_{top}= 172.4 +- 1.2 GeV
- **Expectations at the LHC:**
  - Δm_{top} ~ 1 GeV
  - Yukawa couplings ~ 20 % (with slight model assumptions)
- **Expectations at the ILC:**
  - Mass via threshold scans: m_{top}~ 100 MeV (theory dominant)
  - Yukawa couplings via $t \bar{t} H$: difficult due to small rates, but < 20%
  - Unique access to electroweak couplings
- **Why are top properties so important?**
  - m_{top} is dominant uncertainty for elw. precision observables
  - ILC precision mandatory already now to exploit theory at quantum level!

Importance of 'top' mass

- Top mass is important input parameter for electroweak precision tests
  - SM prediction for m_W and $\sin^2\theta_{eff}$: consistency checks, sensitivity to m_{Higgs}
  - compare m_W and $\sin^2\theta_{eff}$: experimental accuracy with theoretical prediction

- Theoretical uncertainties

  1. unknown higher orders: $\Delta \sin^2\theta_{eff}^{ho} \sim 5 \times 10^{-5}$, $\Delta m_W^{ho} \sim 4$ MeV

- High precision of top mass mandatory to exploit theory at quantum level!

If $\Delta m_{top} \sim 1$ GeV (LHC):	$\Delta \sin^2{}_{eff}^{input} \sim 3 \times 10^{-5}$,	$\Delta m_W^{input} \sim 6$ MeV
If $\Delta m_{top} \sim 0.1$ GeV (ILC):	$\Delta \sin^2{}_{eff}^{input} \sim 0.3 \times 10^{-5}$,	$\Delta m_W^{input} \sim 1$ MeV

Only SM-like Higgs at early LHC

- **Interpretation for ILC**
  - **best-suited for studying Higgs properties**
  - **precise determination of couplings:**

    determination of $Hb\bar{b}$ is crucial!
  - **distinction: SM- versus SUSY Higgs**
  - **$t\bar{t}H$ and trilinear Higgs couplings challenging**

- **But is then really 500 GeV as 1st step needed?**
  - **Optimize running scenarios (tunable energy, polarization to separate channels / background)**

Important Higgs 'energy steps'

- **First mass measurements done at 500 GeV:** ΔmH~0.04%
- **For a light Higgs: e+e- -> ZH important**
- **Threshold scans**
  - for best mass resolution
  - spin and CP-properties
- **Branching ratios, couplings**:
  - about threshold (mZ+mH)+50 GeV (~σ maximal)
- **Successful studies done at the top threshold**

Something 'new' detected at early LHC

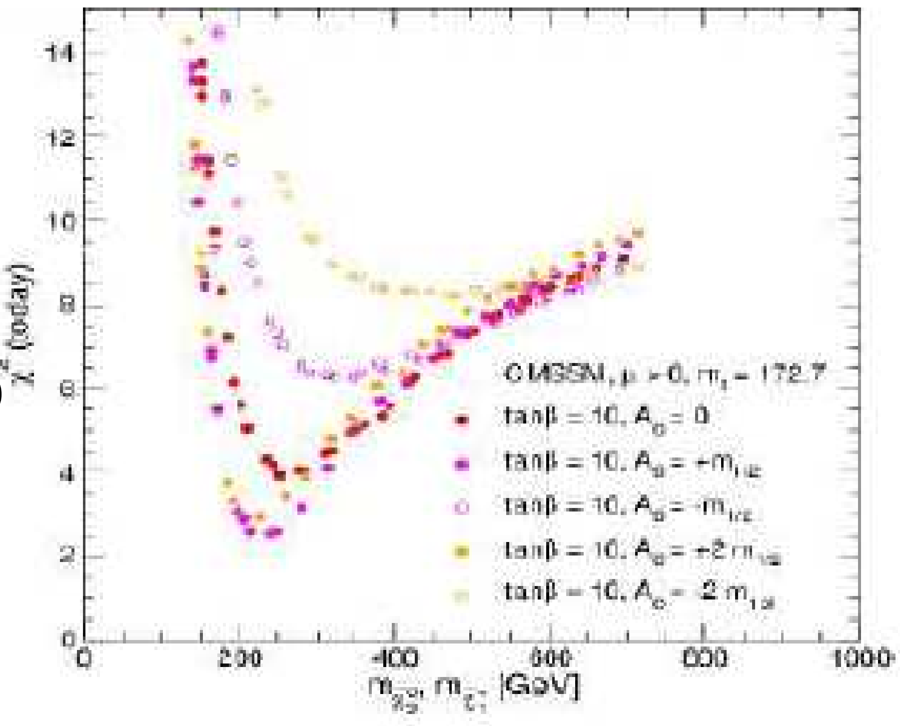
- **SUSY-like signals**
  - **At least partial spectrum accessible at ILC**
  - **Many new parameters (105)**
  - **Reveal new sources of CP-violation**
- **Extra gauge bosons and/or large extra dimensions**
  - **High precision in indirect searches allow model distinction and couplings determination**
- **Which running scenarios and design issues?**

Where do we expect SUSY?

•Fits of electroweak precision observables in concordance with all experimental bounds

At least a few particles should be accessible up to 500 GeV

•For instance: light chargino (LEP bound >104 GeV) between 200-250 GeV



•High L at 500 GeV required!

Features required for LC physics

- ***High statistics*** **needed**
  - **$L = 2 \times 10^{34}\ cm^{-2}\ s^{-1}$**
- **Clean experimental environment**
  - ***low beamstrahlung*** **(Υ_{ave}=0.048)**
  - **precise *luminosity* ($\Delta L<10^{-3}$) and**
    energy* (Δsqrt(s)<200 ppm) *measurement
- **Excellent detector resolution**
  - ***b-, c-tagging*** **(even the charge if needed)**
  - ***τ-polarization***
  - **4π – ε angle coverage**
  - **exloitation of angular distributions, BR's, T's**

Needed features, cont.

- ***Threshold scans***
  - ***Tuneable energy*** **allows to vary energy around the mass threshold of new particles**
  - **Cost luminosity**
  - **Optimization of required energy steps a priori possible via rather accurate continuums measurements**
- ***Beam polarization***
  - **Polarized e- with P(e-)~90% expected**
  - **Polarized e+ with P(e+)~60% (even in baseline ~30% expected !)**
  - **Enable to reveal underlying structure of new physics**
  - **Enhance statistics**

Undulator@150 vs 250 GeV

(See also EUROTEV-Report-2005-015-1)

- **Only some physics thoughts (see also weblog, July 08)**
- **250 position: higher yield (about a factor ~3)**
  but lumi problems for low $\sqrt{s}$
  - **For current parameters: drops below design value 1.5 from $\sqrt{s}$=300 GeV downwards**
  - **Possible lumi loss could be compensated by using bypass and half rate if lumi drops by factor 2**
  - **For current parameters this should happen between 200-240 GeV**
- **What's about expected physics in this energy range?**

Physics at $\sqrt{s}$=200-300 GeV

- **Light Higgs:**
  - should be in range [115 – 180] GeV, that means
  - first measurements will be done at 500 and 350 GeV and predict optimal steps for threshold scans
  - Higgs mass in continuum up to 50 MeV
  - Threshold scans needed, e.g. for spin verification: 3 steps needed
  - Couplings measurements optimal at 50GeV+threshold: -> almost beyond critical region
    σ(HZ)+50 GeV -> [260-320] GeV
    or at top threshold: anyway ok

Which other physics is crucial?

- **Top threshold:** happens at 350 GeV…..ok
- **Light SUSY:** …..would be lovely…
  - Remember: ew. Fits are consistent with mX~200 GeV….
  - studies will anyway be done first at 500 GeV
  - If threshold scans required, number of needed energy steps optimized via the continuum measurements (similar as for Higgs)

Why polarized e^- and e^+ beams?

- **Comprehensive overview in *hep-ph/0507011, Phys.Rept.460 (2008), GMP et al.***
  - **executive summary: *http://www.ippp.dur.ac.uk/LCsources/***

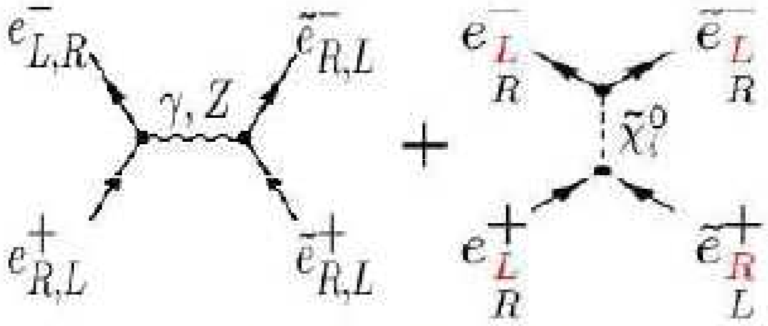
- Goals: Polarized beams required to
  - analyze the structure of all kinds of physics
  - improve statistics: enhance rates, suppress backgrounds
  - get systematic uncertainties under control

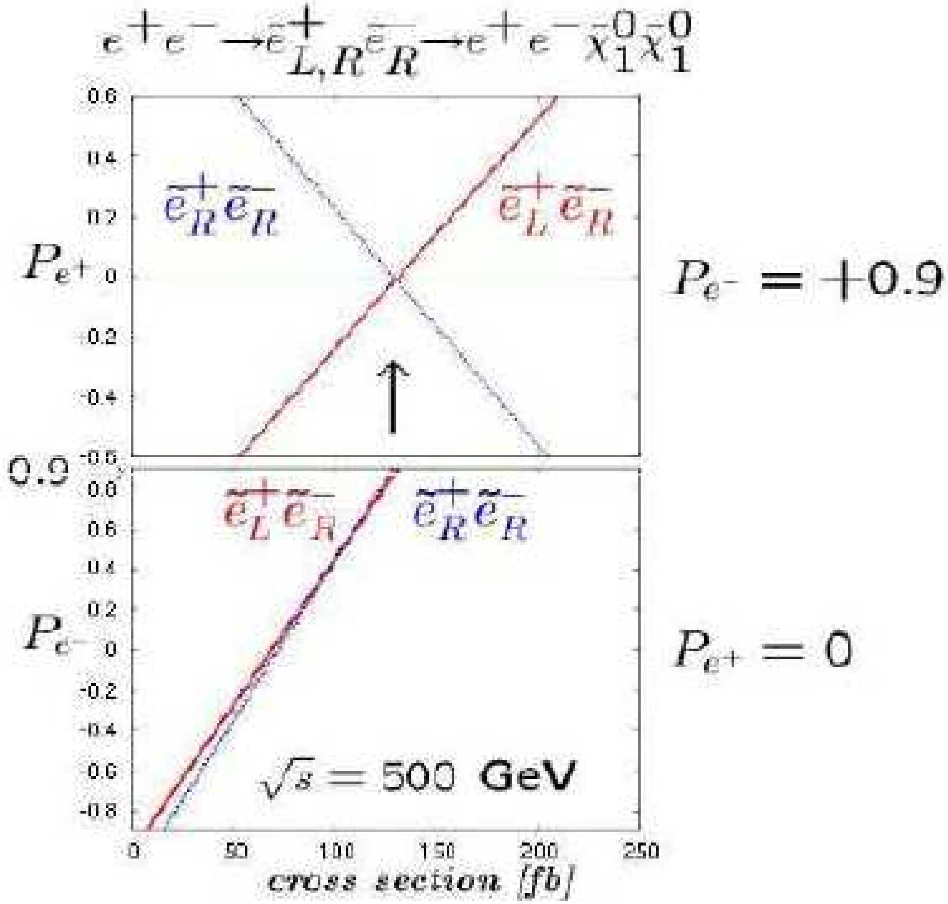
- **Exist example where even a 100% e- beam is not sufficient, P(e+) is really required….→ report**
- **High precision measurements at GigaZ**
  - **require polarized e- and e+ beams as well**

New physics where P(e+) required

- Association of chiral electrons to scalar partners $e^-_{L,R} \leftrightarrow \tilde{e}^-_{L,R}$ and $e^+_{L,R} \leftrightarrow \tilde{e}^+_{R,L}$:

s-channel t-channel





1. separation of scattering versus annihilation channel
2. test of 'chirality': only $\tilde{e}^+_L \tilde{e}^-_R$ may survive at P(e-) > 0 and P(e+) > 0 !

- *Even high P(e-) not sufficient, P(e+) is substantial!*

Background suppression

WW, ZZ production = large background for NP searches!

W^- couples only left–handed:
$\rightarrow WW$ background strongly suppressed with right polarized beams!

Scaling factor= $\sigma^{pol}/\sigma^{unpol}$ for WW and ZZ:

$P_{e^-} = \mp 80\%$, $P_{e^+} = \pm 60\%$	$e^+e^- \rightarrow W^+W^-$	$e^+e^- \rightarrow ZZ$
(+0)	0.2	0.76
(−0)	1.8	1.25
(+−)	0.1	1.05
(−+)	2.85	1.91

Enhancing eff. lumi

- Effective polarization

$$P_{eff} := (P_{e^-} - P_{e^+})/(1 - P_{e^-}P_{e^+})$$
$$= (\#LR - \#RL)/(\#LR + \#RL)$$

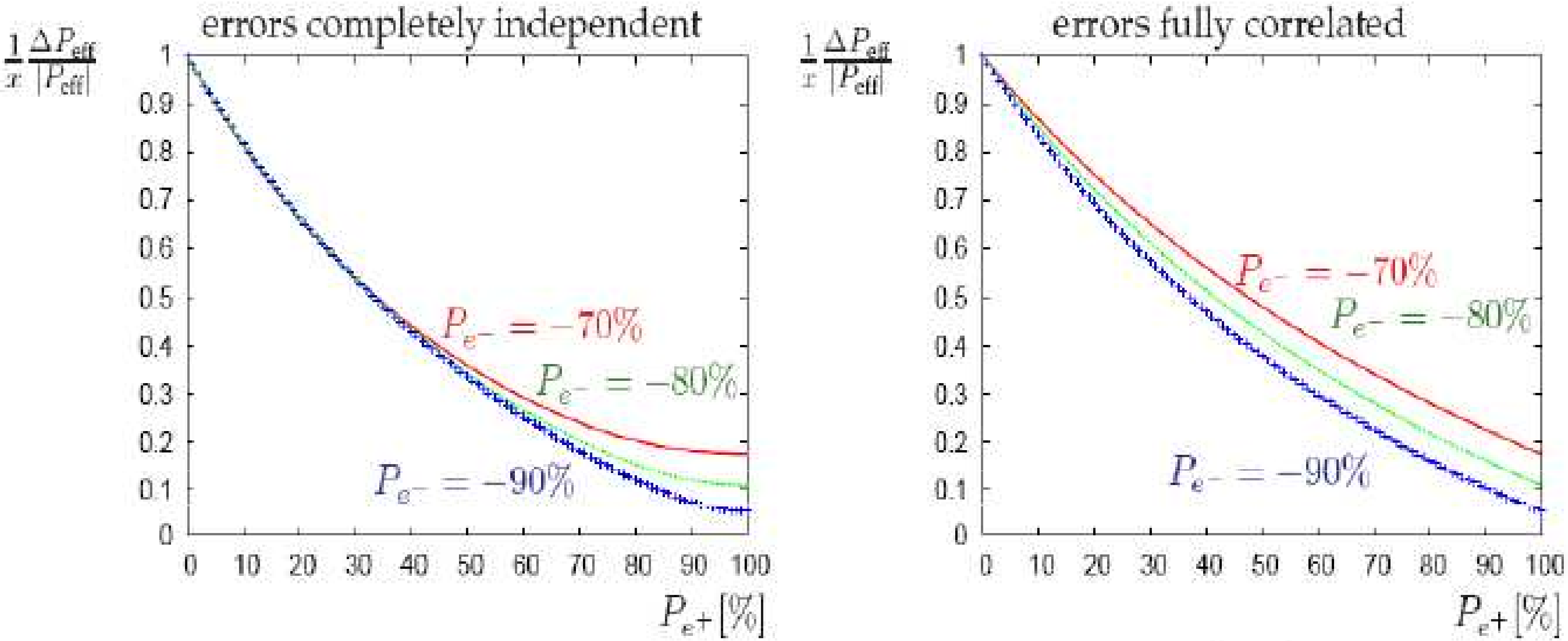
- Fraction of colliding particles
$\mathcal{L}_{eff}/\mathcal{L} := \frac{1}{2}(1 - P_{e^-}P_{e^+}) = (\#LR + \#RL)/(\#all)$

Colliding particles:

	RL	LR	RR	LL	P_{eff}	$\mathcal{L}_{eff}/\mathcal{L}$
$P(e^-) = 0$, $P(e^+) = 0$	0.25	0.25	0.25	0.25	0.	0.5
$P(e^-) = -1$, $P(e^+) = 0$	0	0.5	0	0.5	−1	0.5
$P(e^-) = -0.8$, $P(e^+) = 0$	0.05	0.45	0.05	0.45	−0.8	0.5
$P(e^-) = -0.8$, $P(e^+) = +0.6$	0.02	0.72	0.08	0.18	−0.95	0.74

$\Rightarrow$ Enhancing of $\mathcal{L}_{eff}$ with $P(e^-)$ and $P(e^+)$!

Importance of P(e+) for A_{LR}



- (80%,60): P_{eff} = 95% (90%,60%): P_{eff} =97% (90%, 30%): P_{eff} =94 %

$\Delta A_{LR}/A_{LR}$ = 0.3 Δ A_{LR}/A_{LR} = 0.27 Δ A_{LR}/A_{LR} =0.5

gain: factor~3 factor>3 factor~2

→ **NO gain with only polarized e⁻ !**

Remember power of GigaZ : Hints for SM versus SUSY?

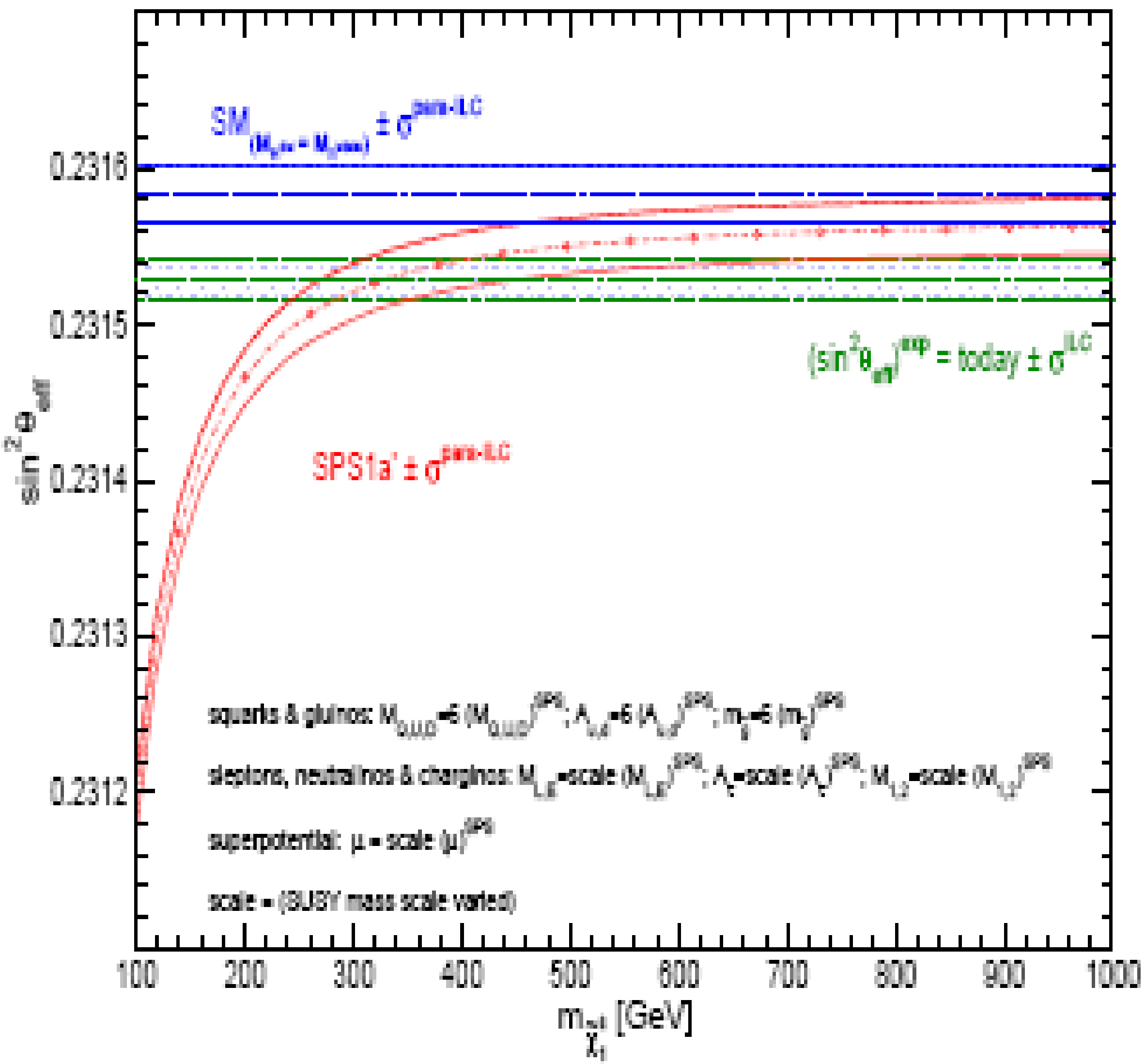
Only Higgs @LHC

No hints for SUSY

- **Measure A_{LR} via Blondel scheme**

- **Deviations in $\sin^2\theta_{eff}$**
  - **hints for SUSY**

- **Powerful test!**
  - **Do not miss it**



Conclusions

- **As far as known today: only few energy steps required at $\sqrt{s}$=200-300 GeV**
  - Both undulator positions 250,150 seems ok
  - Include half-pulse option to keep lumi loss to factor 2 below $\sqrt{s}$<250 GeV
- **GigaZ:** by-pass mode and 2nd source option
- **Full lumi at 2xmtop and at 500 GeV required**
  - More concerned about the lowP option: L/2 even at high energy run ….. not acceptable
  - **Please remember requirements of scope documents!**

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Two scenarios considered

- Take machine “as is” [scenario 1]
  - No additional $$$
  - luminosity constrained by e^+ source efficiency
- Second e^+ source driven by e^- beam accelerated in unused section of e^+ linac
  - High luminosity Z factory
  - Polarised e^+
  - $$$ [but cheaper than a “conventional”

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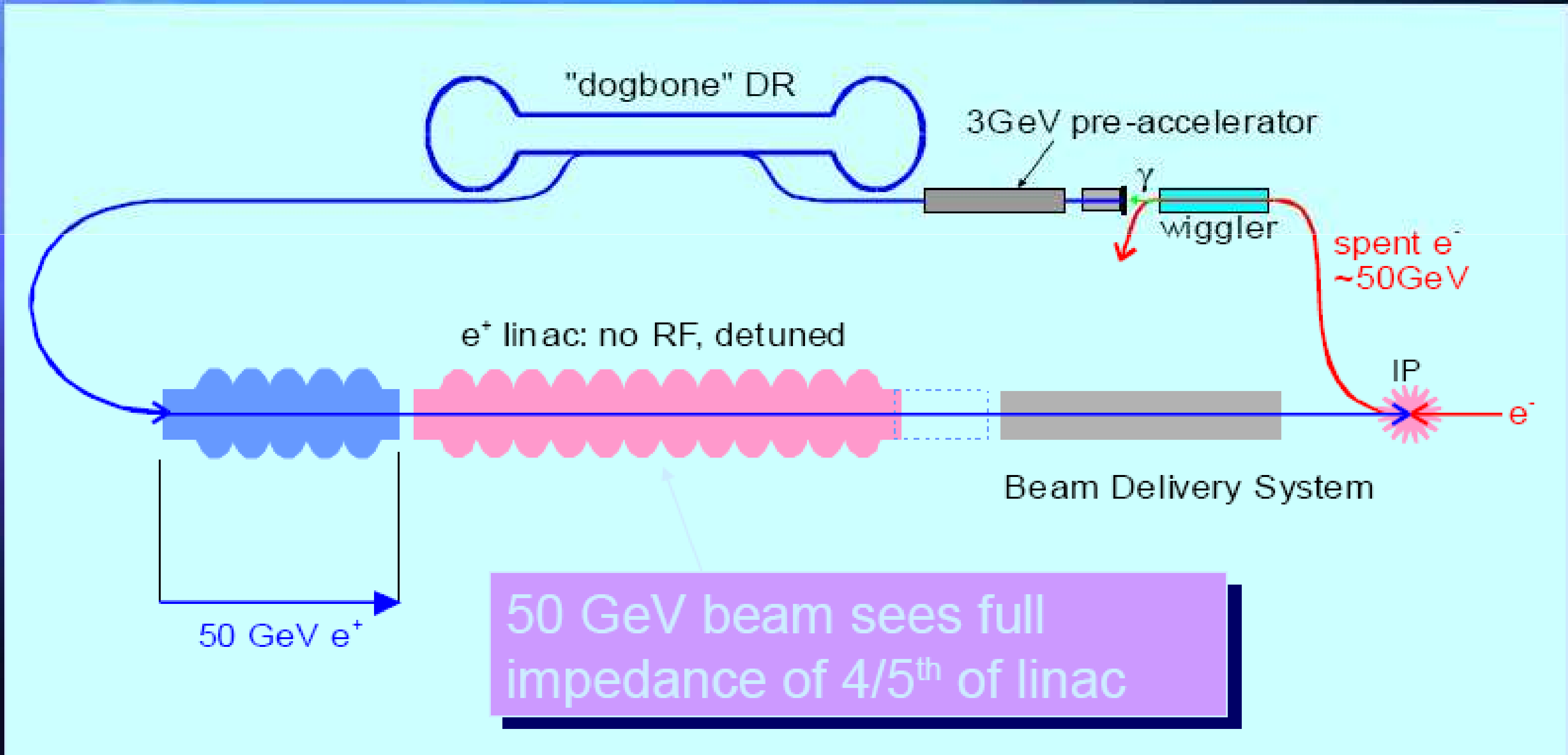
Scenario 1: minimal approach



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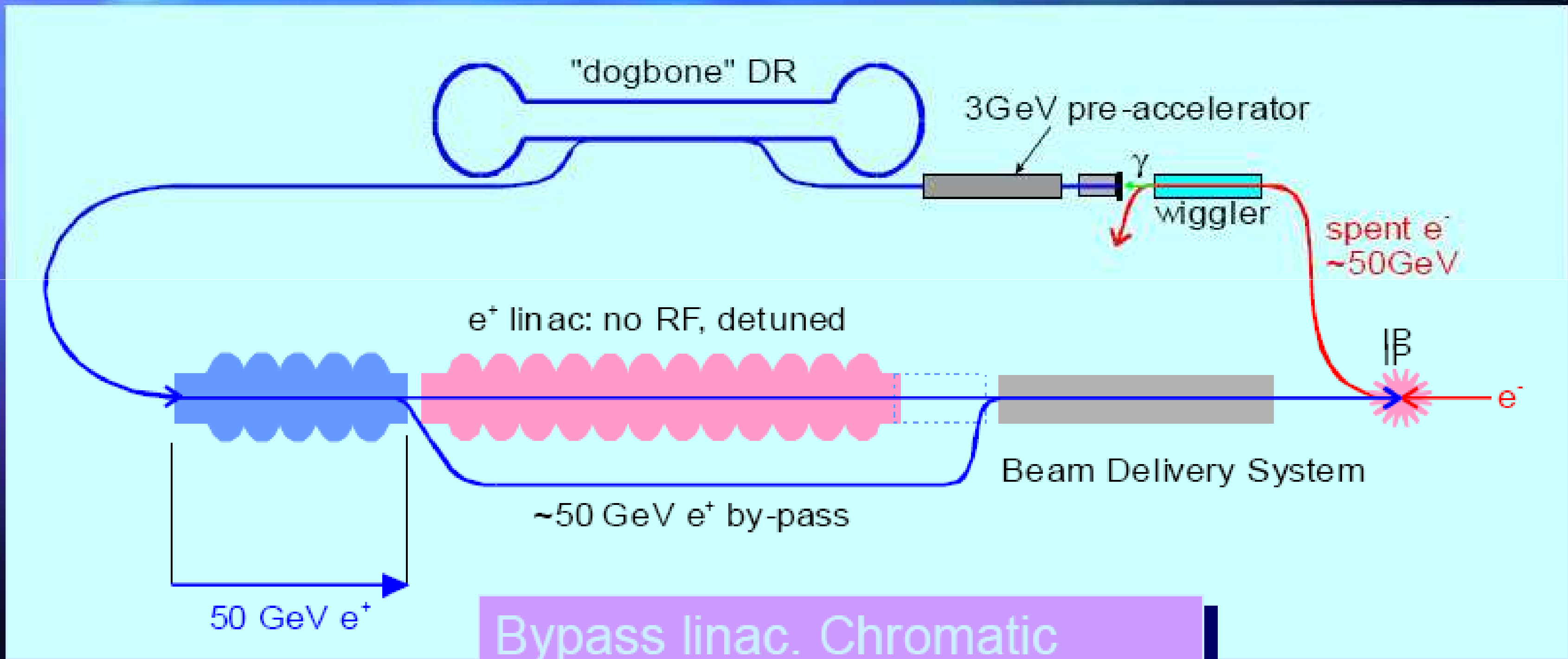
Scenario 1 with linac bypass



Bypass linac. Chromatic emittance growth only

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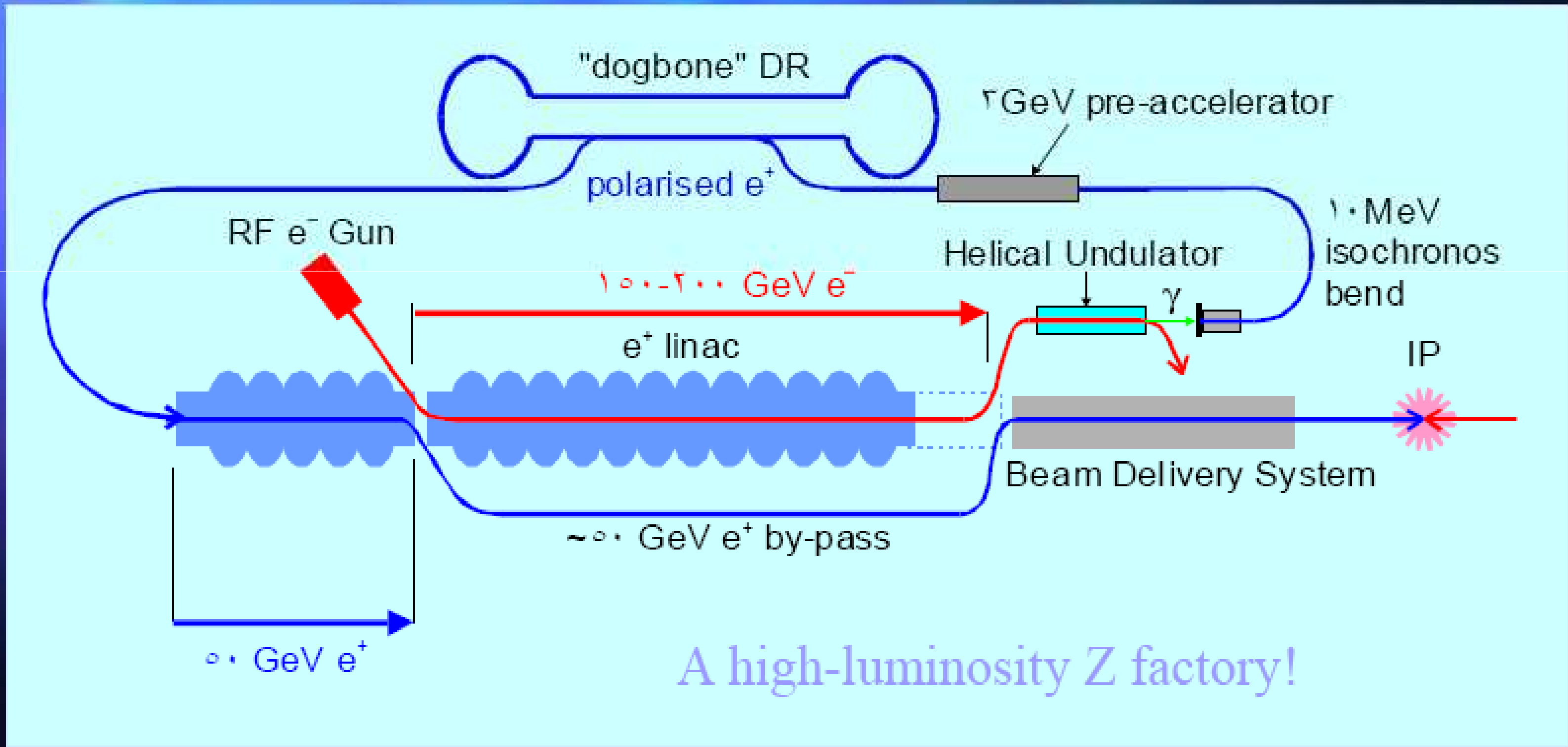
Scenario 2: new e^+ source



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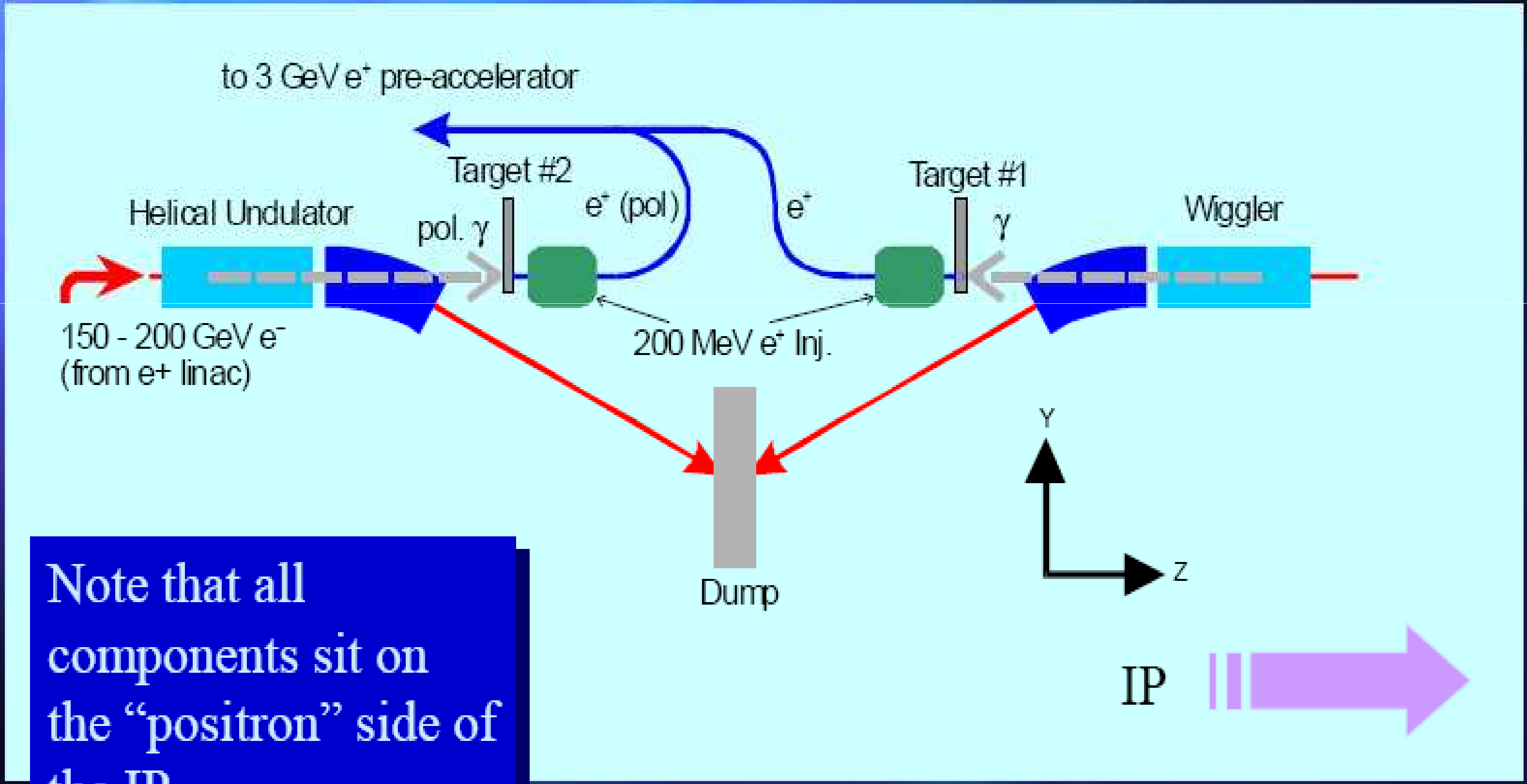
Concept of second e^+ source



Note that all components sit on the "positron" side of the IP

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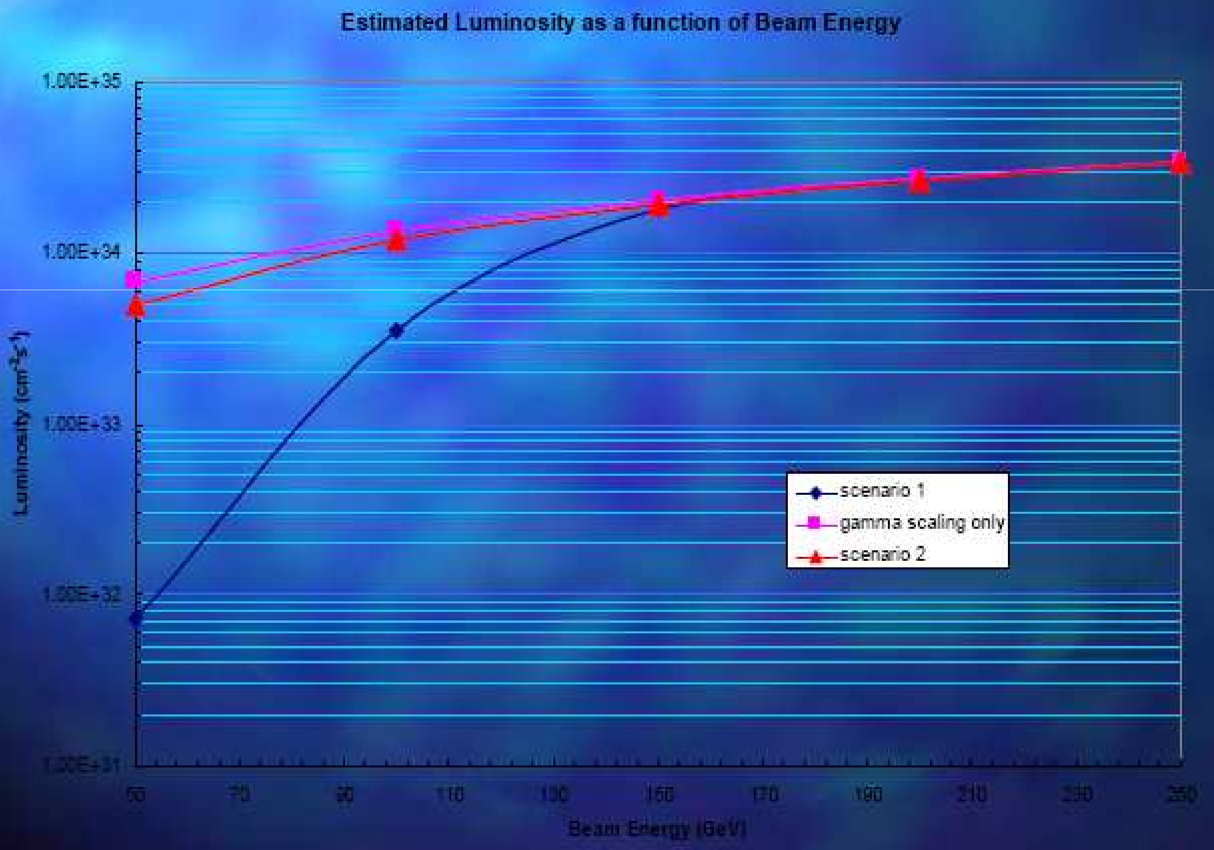
Estimates of Luminosity



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Beam energies between 50 and 250 GeV

- 50→100 GeV
  - use secondary source
  - 200-150 GeV e^- beam available from unused section of e^+ linac
  - more than one bypass exit?
- 150 →250 GeV
  - use spent beam source
- 100 →150 GeV
  - good question!