The Role of Positron Polarisation at 250 GeV

J. List, December 8 2017
ILC @ DESY General Project Meeting

Overview

- “Physics Case for the 250 GeV Stage of the International Linear Collider” => arXiv:1710.07621
- assumes |P(e-,e+)| = (80%,30%),
  with luminosity sharing (-+,+-,—,++)=(45%,45%,5%,5%)
- shows e.g. Higgs coupling precisions in comparison to the unpolarised case
- but how important is the |P(e+)|=30% at 250 GeV?
- what would we loose when |P(e-,e+)|=(80%,0%),
  with (- ,+)=(50%,50%)?

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P(e+)=0

Yet another document…

- Lyn Evans asked LCC Physics WG to make a statement on positron polarization
- one phone meeting with physics WG **“+friends”**
- first complete draft (~16p) circulated on Dec 1, currently implementing comments
- submit to arXiv by Dec 15
- if you would like to comment / contribute before submission, let me know!

December 8, 2017

The role of positron polarization at the 250 GeV stage of the International Linear Collider

LCC Physics Working Group

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ABSTRACT

The International Linear Collider is now proposed with a staged machine design, with the first stage at 250 GeV and a luminosity goal of 2 ab^{-1}. One of the questions for the machine design is the importance of positron polarization. In this report, we review the impact of positron polarization on the physics goals of the 250 GeV stage of the ILC.

Outline

- Introduction
- Polarization Basics
- Determination of the Beam Polarization
- Precision Characterization of the 125-GeV Higgs boson
- Standard Model Precision Measurements
  - Cross sections and Asymmetries
  - CP Violation
- Physics beyond the Standard Model
- Conclusions

Introduction

1. **enhance signals / reduce backgrounds:**
    - better S/B => “saves” integrated luminosity
    - sensitivities don’t combine linear: combination of results from e.g. two data sets with small and large S/B, respectively, is more sensitive than a single data set with the same total number of signal and background events.
2. **4 data sets (-+,+-,—,++) vs 2 data sets (- ,+):**
like-sign configurations contain additional and sometimes unique information
3. **control of systematic uncertainties:**
actually achieving the experimental uncertainties we claim requires sufficient redundancy to determine all relevant nuissance parameters in-situ.

Determination of the Beam Polarisation

- we have a real-life example of a LC with electron polarization only: SLC!
- famous measurement of A_LR (Z pole)
- **still today have an unresolved > 3 sigma discrepancy between A_LR from SLC and A_FB^b from LEP**
- at the time, every stone was turned - one of them:
  Was the positron polarization really 0?
- *no* independent means to control positron polarization in-situ
- no convincing model *how* the positron beam could have been polarized
- but still: under considerable effort, a separate experiment (with Moeller and Bhabha polarimeters in Endstation A beamline) was built *a posteriori*
- could confirm P(e+)=0 within 0.07%

P. Rowson, T. Wright, H. Band, "The Positron Polarization (Posipol) Experiments : T419," SLD note # 268 (2000), http://www-sldnt.slac.stanford.edu/sldbb/SLDNotes/sld-note%20268.pdf.

=> lesson: even for P(e+)=0, need the positron polarimeter and the fast helicity reversal, use polarimeter constraint in global fits

Precision Characterization of the 125-GeV Higgs boson

- P(e+)=0: ~20% less ZH events in 2 ab-1 @ 250 GeV (420k vs 500k) => 20% longer running time (~2 years) for same data set
- Standard EFT fit: 6..10% degradation max. - but complex interplay of observables, assumptions on systematics, theory
- systematics used in EFT fit:
  - 0.1% on luminosity
  - 0.1% on polarization
  - 0.5% on b-tagging
  - no uncertainty on background

	0%/0%	80%/0%	80%/30%
$g(hbb)$	1.3	1.1	1.1
$g(hcc)$	2.1	2.0	1.9
$g(hgg)$	1.9	1.8	1.7
$g(hWW)$	0.98	0.68	0.67
$g(h\tau\tau)$	1.5	1.3	1.2
$g(hZZ)$	0.97	0.69	0.68
$g(h\gamma\gamma)$	1.4	1.2	1.2
$g(h\mu\mu)$	5.7	5.6	5.6
$g(h\gamma Z)$	14	6.7	6.6
$g(hbb)/g(hWW)$	0.91	0.91	0.86
$g(h\tau\tau)/g(hWW)$	1.1	1.1	1.0
$g(hWW)/g(hZZ)$	0.07	0.07	0.07
Γ_h	2.9	2.6	2.5
$BRh \to inv$	0.36	0.33	0.32
$BRh \to other$	1.7	1.7	1.6

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In addition TGCs and EWPOs are important in EFT fit:
- kept same independent of P(e+)
- TGCs only in most constrained parametrisation

SM: Cross sections and asymmetries [R.Karl]

- most comprehensive study so far on simultaneous measurement of
  - beam polarizations, (unpolarised) cross sections and left-right asymmetries
  - using total cross sections, angular distributions and a polarimeter constraint
  - of WW, singleW, Z(gamma) processes
- observations:
  - P(e-) always well constrained to 0.1% or better
  - ***no* polarimeter constraint for P(e+):**
    uncertainties on P(e+), cross sections and
    asymmetries **~ 10x larger in case P(e+)=0**
  - ***with* polarimeter constraint P(e+)=0 ±0.25%:**
    ~ 2-3 x larger uncertainties in case P(e+)=0
  - **with 1σ *bias* between polarimeter and IP:**
    - **P(e+)=0: bias transfers to observables**
    - **P(e+)=30%: less so - and: can fit also w/o polarimeter constraint and thus pin-down!**
    - fully avoid: need more like-sign luminosity, e.g. (40%,40%,10%,10%)

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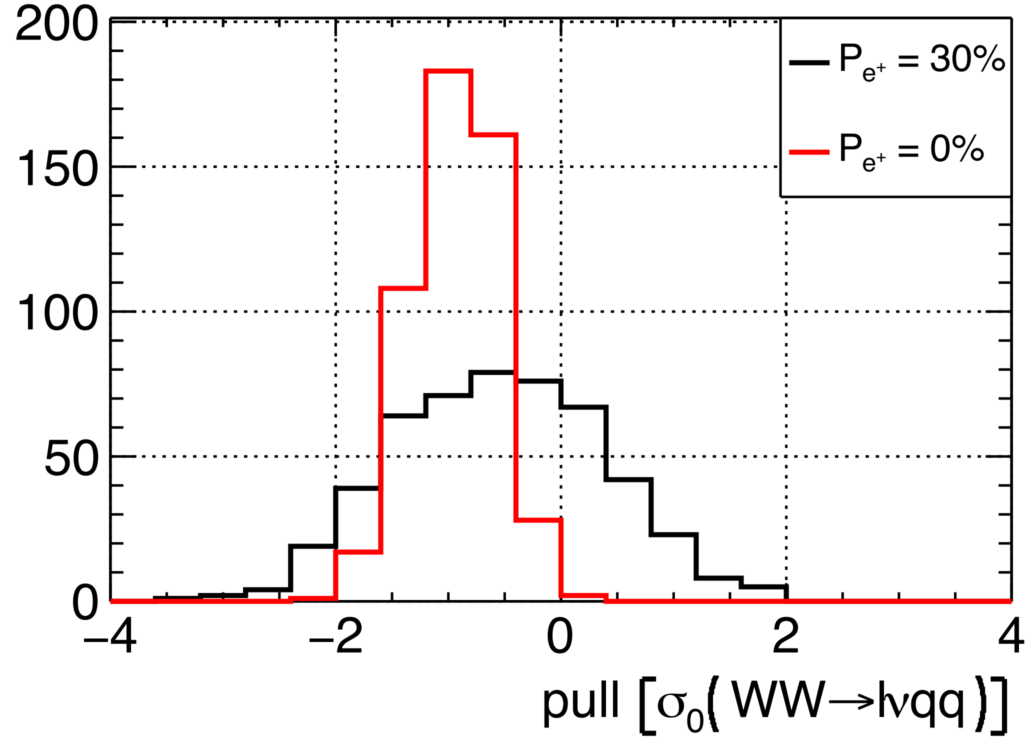
Example:
transfer of 1sigma offset polarimeter-IP on extracted WW->qqlv cross section



SM: CP Violation

- quark sector does not give enough CPV => new sources of CPV in Higgs/EW sector?
- typically requires *transverse* polarisation
- not in official scenario, but technically not a problem:
  - spin rotators & polarimeters ok
  - for non-CP measurements, transverse polarisation looks like unpolarised beam (c.f. LEP, HERA-I)
- examples:
  - most general (c)TGCs: 14 complex couplings = 28 real parameters
    => h+ requires both beams transversely polarised
    => not accessible in case of P(e+)=0
  - similarly for neutral TGCs from gamma-Z-production:
    CP sensitive terms bi-linear in electron and positron polarization
    => not accessible in case of P(e+)=0

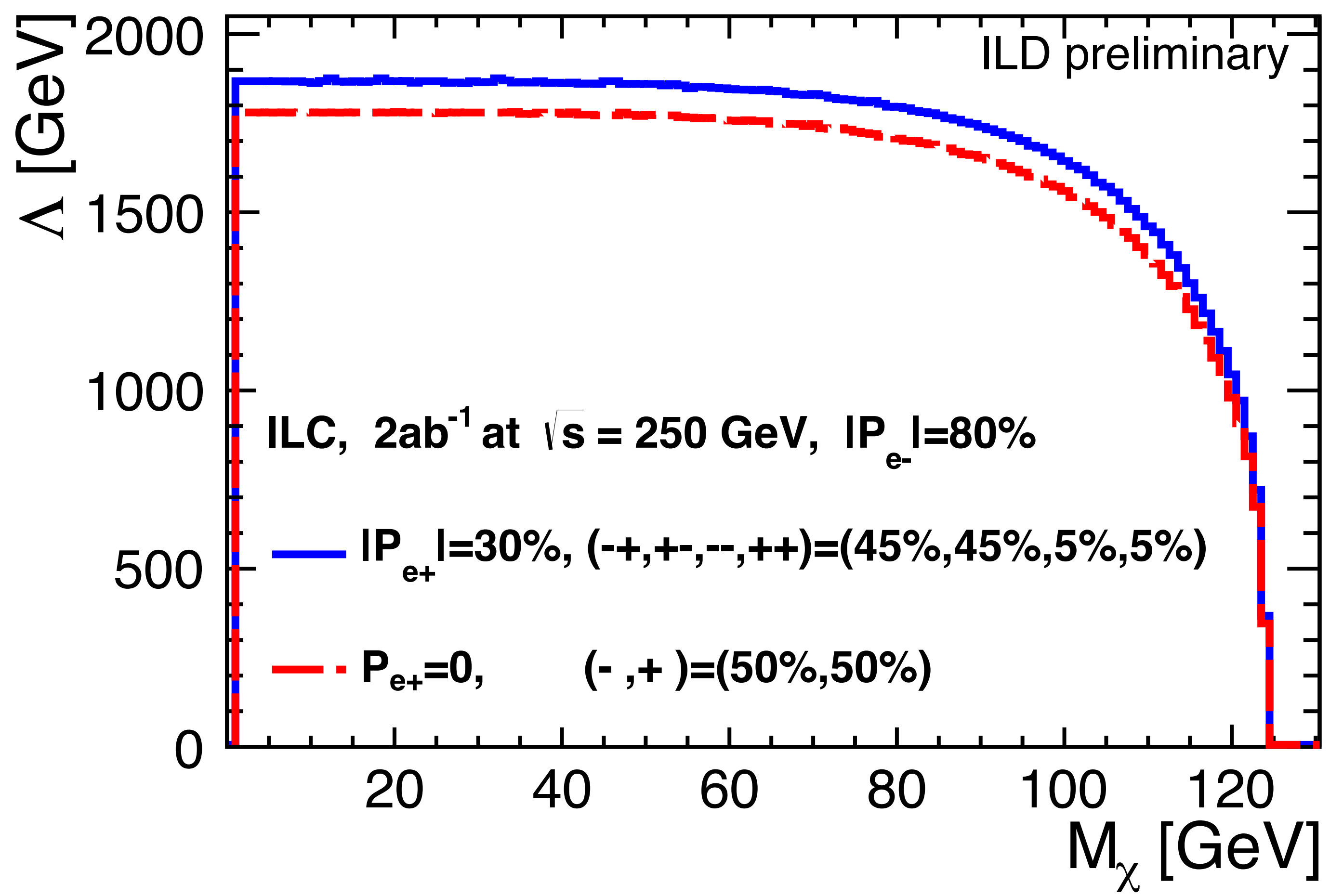
M.Diehl, O.Nachtmann, F.Nagel, EPJC 32 (2003) 17

Physics beyond the Standard Model

- **Special role of positron polarization in model-independent characterisation of a BSM signal, chiral properties of new particles / new interaction**
  => need P(e+) only *after* a discovery has been made?
  Or: can we discuss “search phase” and “post-discovery phase” separately?
- in some example yes, e.g. plain-vanilla SUSY with light s-electrons which would give many sigma after few weeks/months => could then add polarized source (caveats: R&D done, construction time, additional cost, …)
- but in general, search, discovery and characterisation will be intertwined: if we end up with medium significance discrepancy after 2ab-1, the additional observables provided by positron polarization could very well give the decisive hint that indeed incompatible with SM, thus discovery, and at the same time narrow down possible interpretations (c.f. 750-GeV story!)

BSM - Examples

- **mono-photon WIMP search: P(e+)=0: reach in NP scale reduced by ~100 GeV**
  => takes ~2.5 years longer running to recover
  P(e+) essential to determine type of operator(s) / mediators



- **heavy leptons:** search for mixing of e and/or ν with heavy partners in W pair production needs | **double polarization asymmetries => impossible without P(e+)**

- **RPV SUSY:** s-neutrino exchange in mumu production
  P(e+) enhances S/B by factor ~2 => considerable increase in discovery reach both in higher masses and smaller RPV couplings

- **Contact Interactions:** *model-independent* search for CI in Bhabha scattering requires cross section measurements for all four helicity combinations
  => not possible with P(e+)=0

Conclusions

- discussed role of positron polarization at 250 GeV:
- *statistical* effects in many cases ~20% in rates
  => can be compensated by longer running time - but:
- positron polarization very important for controlling *systematic* uncertainties (which are often are included only to a limited extent in current studies!)
- having 4 instead o 2 data sets enables more model-independent interpretations, both in absence and in presence of discoveries
  - clear-cut discovery: essential to determine underlying physics
  - real-life: decisive handle to identify an (otherwise) medium significance observation as incompatible with the SM, thus as a *real* discovery