Polarization dependency of coherent IP QED backgrounds

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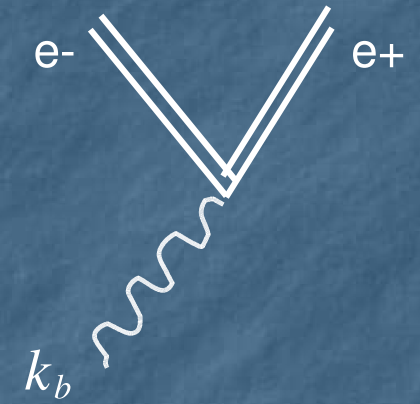
- Review CAIN polarization dependency of coherent processes
- Introduce *new* coherent Breit-Wheeler process
- Discuss simplifications of analytic forms and implementation into CAIN

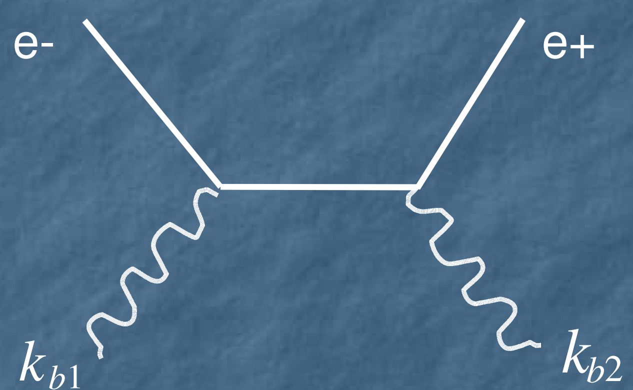
CAIN polarization effects

- Coherent pair production
  - fermion wavefunction solutions in beam field



$$n\,k + k_b \rightarrow e^- + e^+$$

LT polarizations



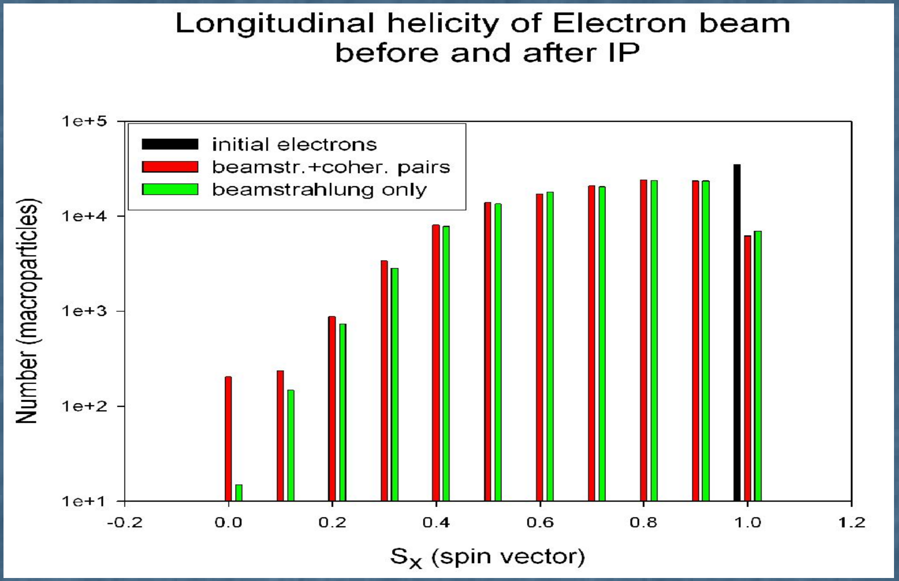
- Incoherent (ordinary) Breit-Wheeler
  - final state polarization ignored

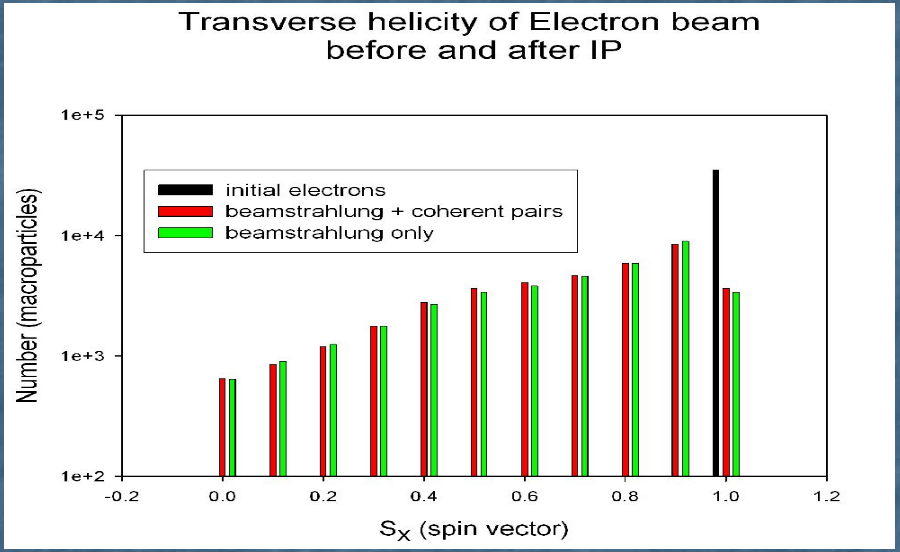
$$k_{b1} + k_{b2} \rightarrow e^- + e^+$$

circular polarization

CAIN- final helicity of coherent pairs

- CAIN has switches to turn on and off coherent pair production
- final polarization states of incoherent pair processes not computed





CAIN – incoherent BW analytic form

$$\frac{d\sigma}{d\cos(\theta)} = \frac{\pi}{2}\frac{m^2}{\omega^2}\frac{p}{\omega} r_e^2 \left(F_0 - F_2 h\right)$$

currently in CAIN

- h is product of circular polarizations of initial photons

- full treatment due to Baier & Grozin hep-ph/0209361

$$\frac{d\sigma}{d\cos(\theta)\, d\phi} = \frac{\alpha^2}{4 s^2 x^2 y^2} \sum_{ii' jj'} F^{ii'}_{jj'}\, \xi_j \xi'_{j'}\, \zeta_i \zeta'_{i'}$$

  - F are simple functions of scalar products
  - s,x,y are Mandelstam invariants

There is nothing particularly complicated about including this in CAIN!

Solution of Dirac equation in beam field A^e

$$\left[(p-eA^e)^2-m^2-\frac{ie}{2}F^e_{\mu\nu}\sigma^{\mu\nu}\right]\psi_V(x,p)=0$$

- Look for a solution of the form: $\psi_V(x,p)=u_s(p)F(\phi)$
- Substitution of the general solution for ψ_V yields a first order d.e. whose solution can be expanded in powers of k,A^e

$$\psi_V(x,p)=\left[1+\frac{e}{2(kp)}\not{k}\not{A}^e\right]\exp[F(k,A^e)]e^{-ipx}u_s(p)$$

- Now look for simplifications by physical considerations

The Volkov solution in more detail

$$\psi_V(x,p) = \left[1 + \frac{e}{2(kp)} \not{k} \not{A}^e\right] \exp[F(x,p,k,A^e)]\, e^{-ipx} u_s(p)$$

make Fourier transform to get linear term in x

$$\int dn \exp[-i(n+\nu^2/kp)kx]\, F_2(p,k,A^e)$$

n term interpreted as a contribution from n external field photons (n can be -ve!)

ν^2 term is a shift in electron momentum

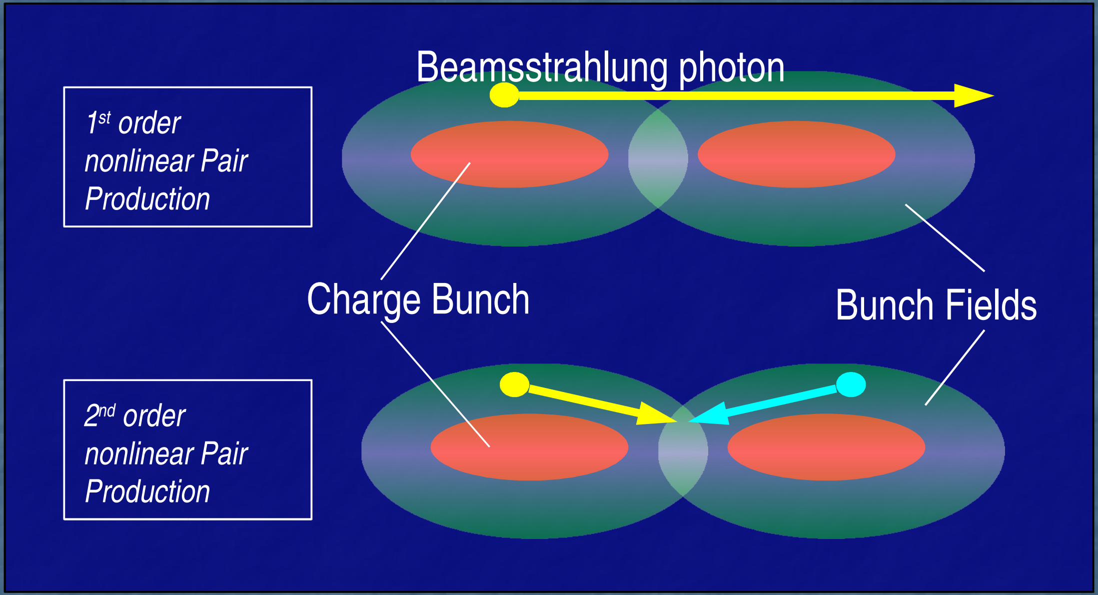
non-external field Dirac solution

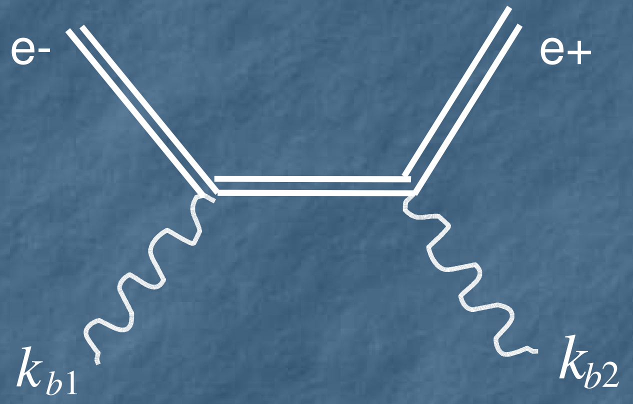
for ILC parameters

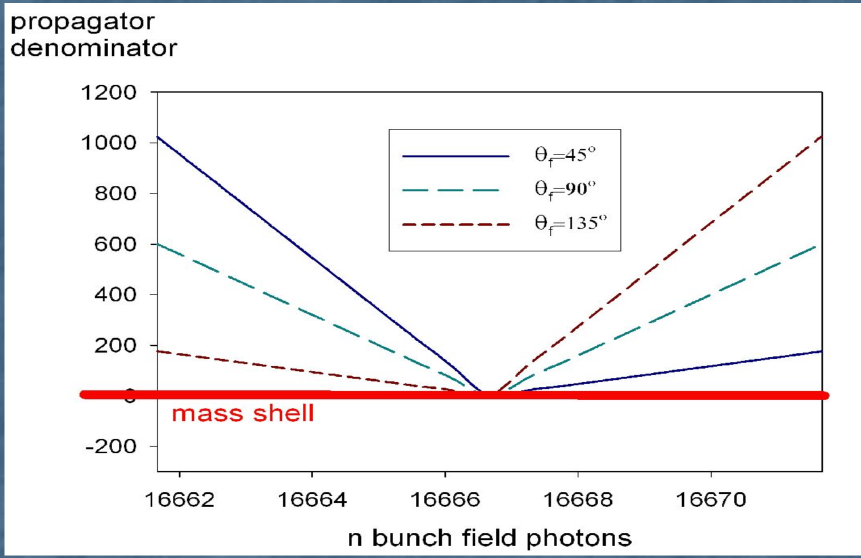
$$\frac{\omega}{m} \approx 0.06 \quad , \quad \frac{e|A^e|}{m} \approx 1$$

so for large E_p second term can be neglected

Coherent Breit-Wheeler process







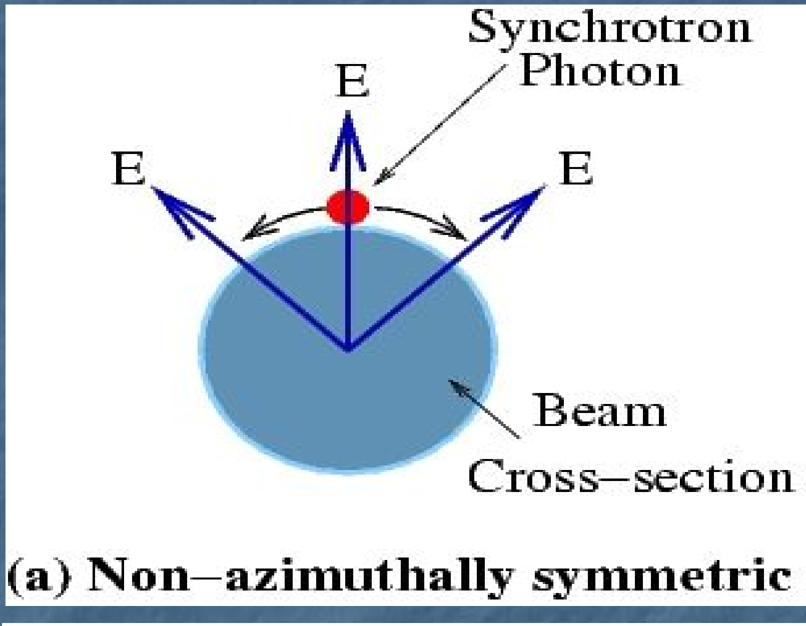
- 2nd order process contains twice as many Volkov E_p
- spin structure same as ordinary Breit-Wheeler
  - fermions recieve a mass shift due to bunch field and the propagator can reach mass shell whenever $n\omega \sim \omega_b$

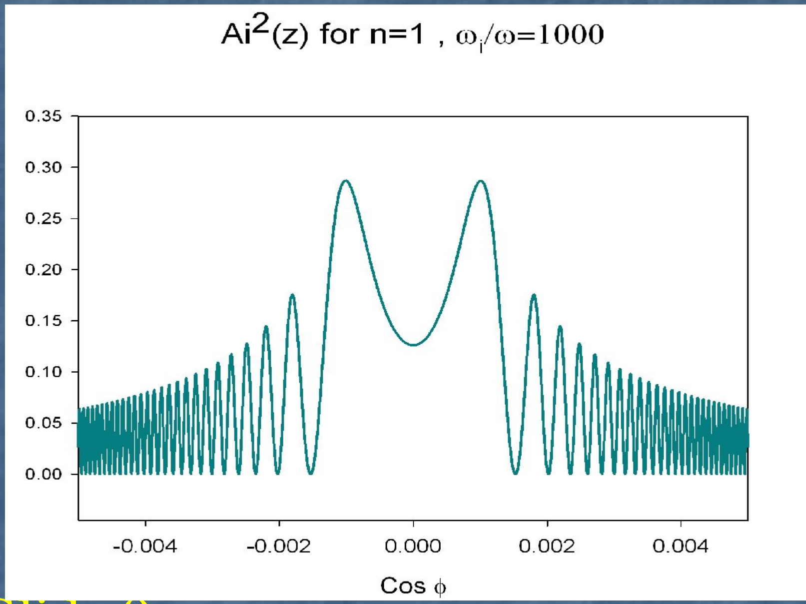
CBW cross-section with simplifications

$$\frac{d\sigma_{CBW}}{d\Omega} \approx \frac{d\sigma_{BW}}{d\Omega} \int_{\neg\omega_1/\omega}^{\infty} \frac{dn}{[(n\omega \pm \omega_1)^2 + \Gamma^2]^2} F$$

- Can write CBW diff x-section as the ordinary BW diff x-section times a numerical factor
- lower bound of integration is determined physically – c of m energy must be at least 2x0.511 MeV
- F is a product of Airy functions for crossed beam field (Bessel functions for circ polarized field)
- Γ is a resonance width determined from a self energy calculation

Numerical function F in more detail

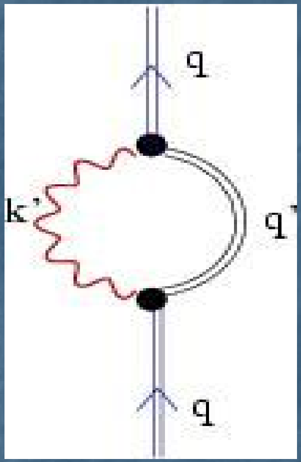




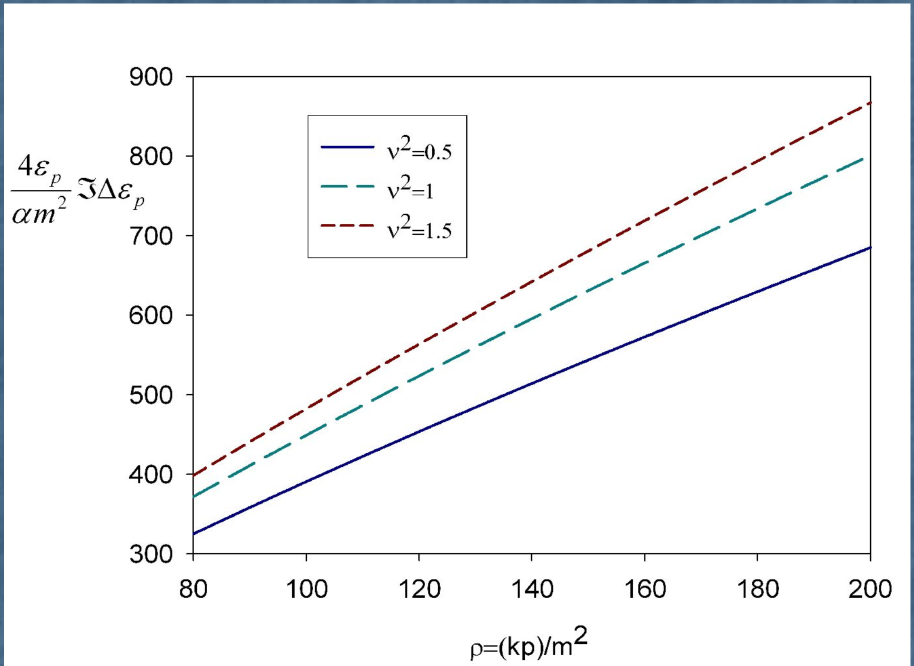
$$F = \int d\phi \, f(\phi) \, Ai^2\left(z(n, \phi, \omega_1/\omega)\right)$$

- dependence on φ due to pair production processes taking place off axis
- difficult to integrate numerically, but will be able to parametrise for CAIN
- Analytic solutions available for some f(φ) – Albright, J Phys A 10(4) 485

Calculation of Resonance widths



- The Electron Self Energy must be included in the Multiphoton Breit-Wheeler process
- This is a 2nd order IFQED process in its own right.
- Renormalization/Regularization reduces to that of the non-external field case



- The Electron Self Energy in external CIRCULARLY POLARISED e-m field originally due to Becker & Mitter 1975 for low field intensity parameter $\nu=(ea/m)^2$. Has been recalculated for general ν
- ESE in external CONSTANT CROSSED field is due to Ritus, 1972
- Optical theorem: the imaginary part of the ESE is the same form as the Sokolov-Ternov equations

Things to do

- include extra polarization dependent terms with existing CAIN processes
- parametrise Volkov solution numerical factor for coherent Breit-Wheeler (CBW) process
- include simplified CBW cross-section as correction to incoherent Breit-Wheeler in CAIN
- determine extent of the contribution to final helicity
- prepare full calculation of CBW for inclusion