# Some Remarks about the Forward Region

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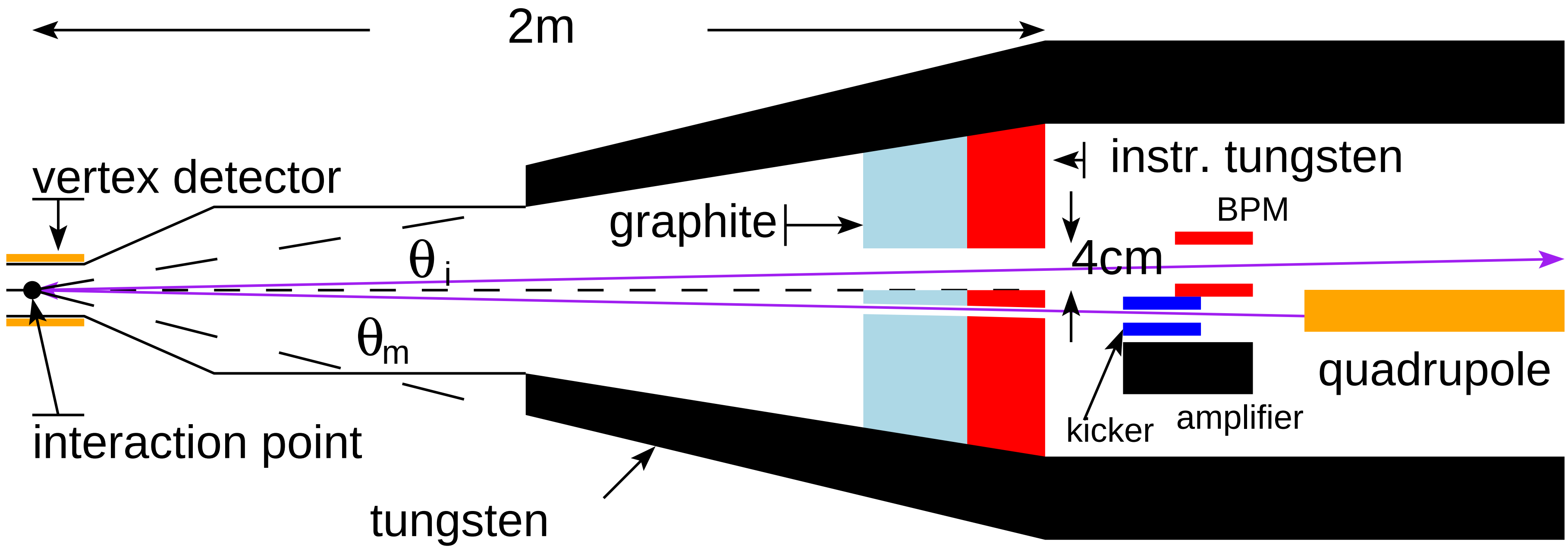
# Interaction Point Layout

- Important components are
  - final quadrupoles, 3.5m from the IP
  - quadrupole support with stabilisation system
    - hope to make a design in the future
  - masks
  - intra-pulse interaction point feedback
  - luminosity monitoring
    - for the moment see fast signal in extraction line only
  - compensating solenoids etc
    - to reduce impact of main detector solenoid on luminosity, being studied
  - specific instrumentation
    - for tuning up the machine, not yet defined
- $L^\star$ and crossing angle have been discussed before

# Mask Design



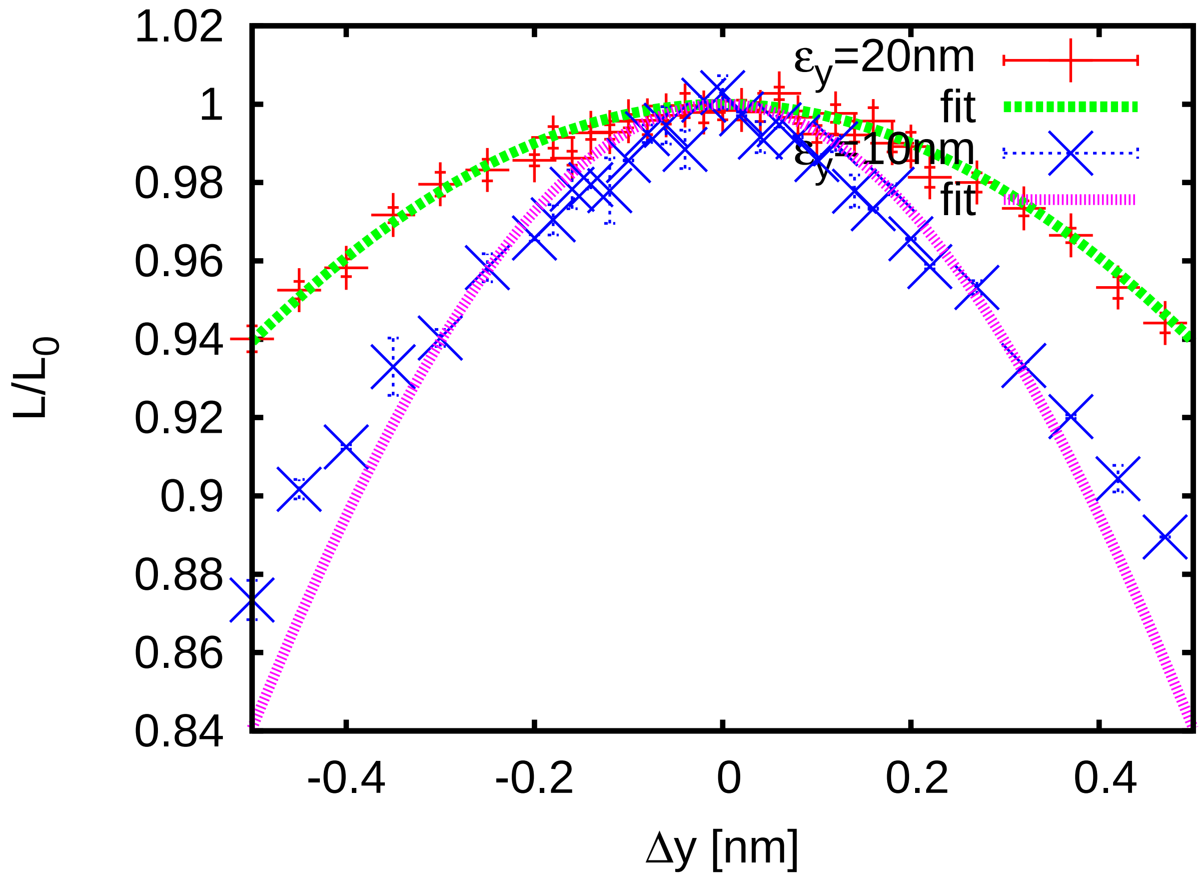

- Current CLIC design corresponds to old TESLA design
  - improvement is possible
  - quadrupole can be further out
- Outer mask suppresses backscattered photons
  - maybe less coverage would be sufficient
- Inner mask prevents backscattering of charged particles
  - distance needs to be small enough that exit hole is smaller than vertex detector (neutrons)

# Beam-Beam Jitter Tolerance

- For a vertical emittance of $20\,\mathrm{nm}$ one finds for $0.2\,\mathrm{nm}$ beam-beam vertical position jitter
  - 1.0% loss with rigid bunch

  $\Rightarrow$ tolerances $0.15$–$0.2\,\mathrm{nm}$
- Inclusion of beam-beam effects finds almost the same values
  - 1.0%
  - 0.28 $\mathrm{nm}$ yields 2.2%

    $\Rightarrow$ tolerances 0.14–0.18 $\mathrm{nm}$



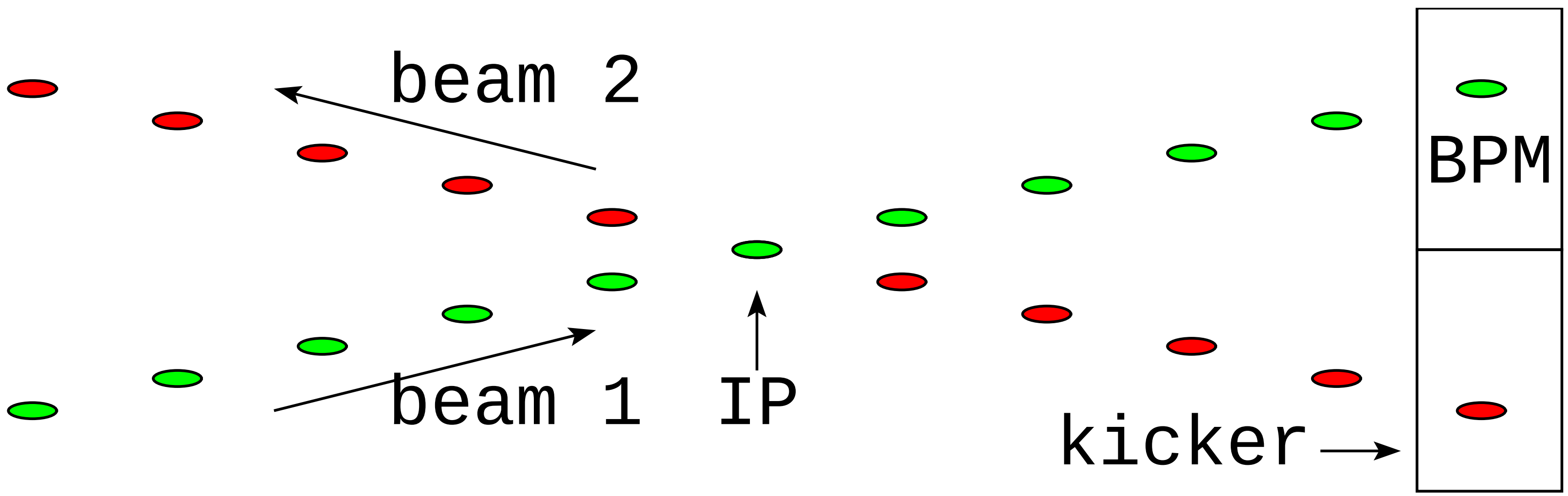

- Limit value for enhancement of coherent beam jitter is

$$\Delta y = \frac{\Delta y_0}{1 - n_c \frac{4Nr_e}{\gamma\theta_c^2}\frac{\delta y'}{\delta \Delta y_0}}$$

- $\Delta y = 1.09\Delta y_0$

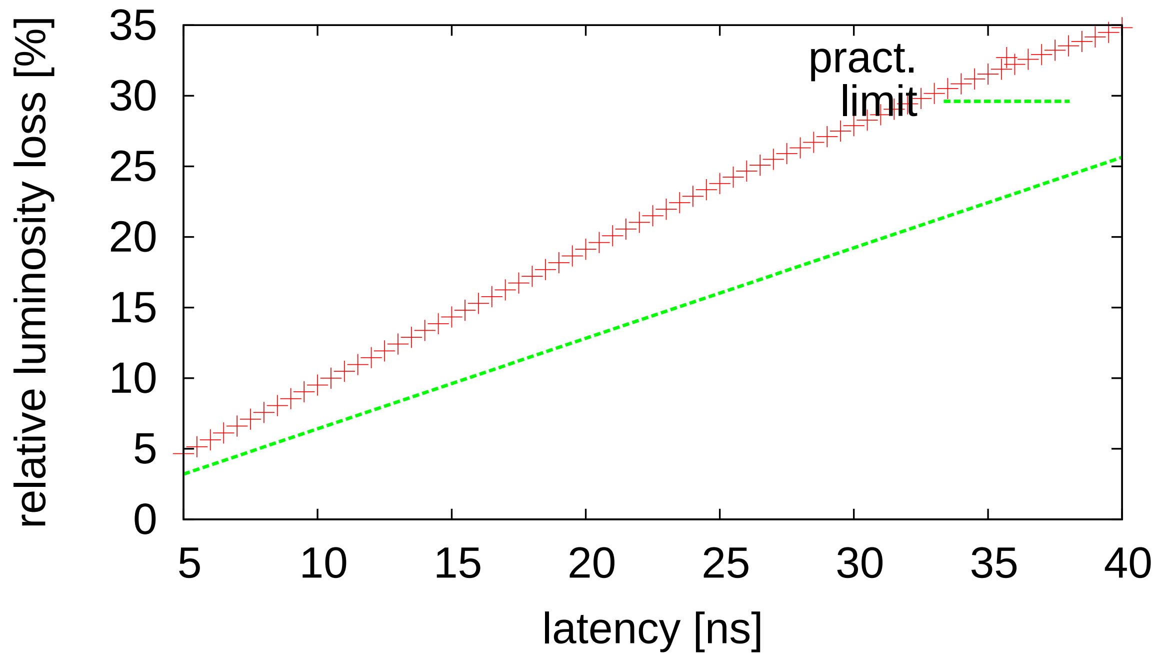
# Intra-Pulse Interaction Point Feedback

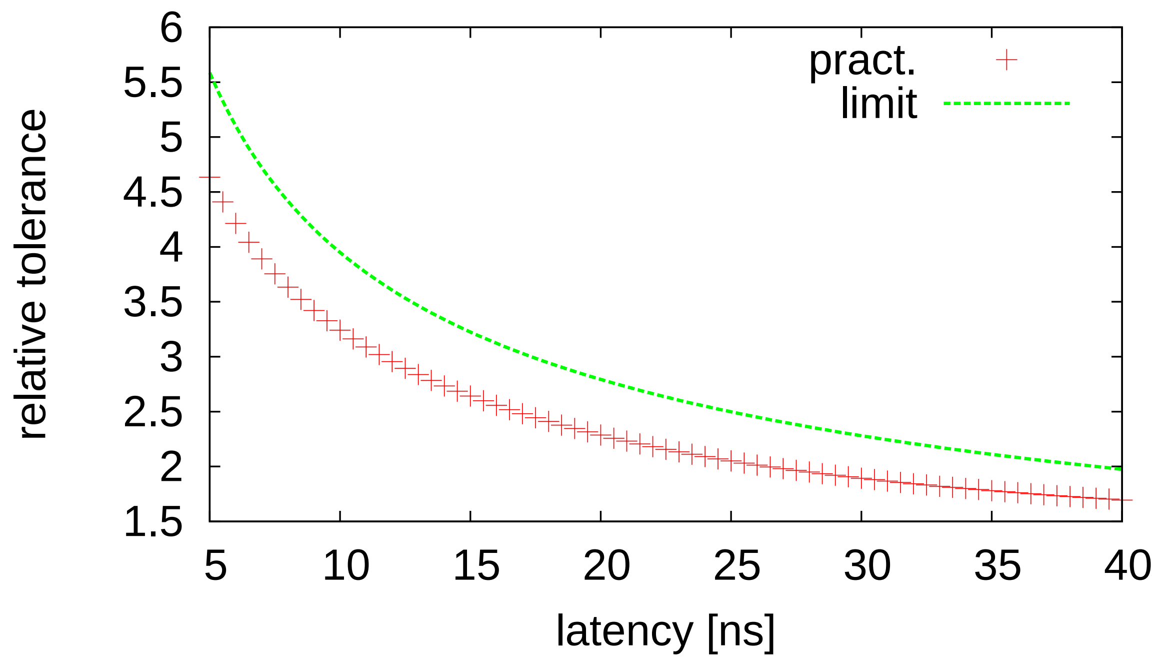
- Reduction of jitter is dominated by feedback latency
  - IP to BPM
  - electronics
  - Kicker to IP
- Assuming 40 ns one can hope for about a factor 2
- Only cures offsets



# Integration of the Intra-Pulse Feedback

- Time of flight to and from IP is critical
- Three main components
  - BPM
  - kicker
  - amplifier
- All need to be close together
- Obvious place behind inner mask
  - does not add material before low angle tagger



# Background Sources

- Machine produced background before IP

  beam tails from linac

  synchrotron radiation

  muons

  beam-gas, beam-black body radiation scattering

- Beam-beam background around IP

  beam particles

  beamstrahlung

  coherent pair creation

  incoherent pair creation

  hadron production

  secondary neutrons

- Spent beam background

  backscattering of particles

  especially neutrons

# Luminosity and Background Values

| | | CLIC | CLIC | CLIC | CLIC(vo) | ILC | NLC |
|---|---|---|---|---|---|---|---|
| $E_{cms}$ | $[TeV]$ | 0.5 | 1.0 | 3.0 | 3.0 | 0.5 | 0.5 |
| $f_{rep}$ | [ $\mathrm{Hz}$] | 100 | 50 | 50 | 100 | 5 | 120 |
| $n_b$ | | 312 | 312 | 312 | 154 | 2820 | 190 |
| $\sigma_x$ | $[nm]$ | 115 | 81 | 40 | 40 | 655 | 243 |
| $\sigma_y$ | $[nm]$ | 2 | 1.4 | 1 | 1 | 5.7 | 3 |
| $\Delta t$ | $[ns]$ | 0.5 | 0.5 | 0.5 | 0.67 | 340 | 1.4 |
| $N$ | $[10^9]$ | 3.7 | 3.7 | 3.7 | 4.0 | 20 | 7.5 |
| $\epsilon_y$ | $[nm]$ | 20 | 20 | 20 | 10 | 40 | 40 |
| $L_{total}$ | $10^{34}cm^{-2}s^{-1}$ | 2.2 | 2.2 | 5.9 | 10.0 | 2.0 | 2.0 |
| $L_{0.01}$ | $10^{34}cm^{-2}s^{-1}$ | 1.4 | 1.1 | 2.0 | 3.0 | 1.45 | 1.28 |
| $n_\gamma$ | | 1.2 | 1.5 | 2.2 | 2.3 | 1.30 | 1.26 |
| $\Delta E/E$ | | 0.08 | 0.15 | 0.29 | 0.31 | 0.024 | 0.046 |
| $N_{coh}$ | $10^5$ | 0.03 | $37$ | $3.8 \times 10^3$ | $?$ | — | — |
| $E_{coh}$ | $10^3 TeV$ | 0.5 | $1080$ | $2.6 \times 10^5$ | $?$ | — | — |
| $n_{incoh}$ | $10^6$ | 0.05 | 0.12 | 0.3 | ? | 0.1 | n.a. |
| $E_{incoh}$ | $[10^6 GeV]$ | 0.28 | 2.0 | 22.4 | ? | 0.2 | n.a. |
| $n_\perp$ | | 12.5 | 17.1 | 45 | 60 | 28 | 12 |
| $n_{had}$ | | 0.14 | 0.56 | 2.7 | 4.0 | 0.12 | 0.1 |

- Target is to have about one beamstrahlung photon per beam particle

  - similar effect to initial state radiation

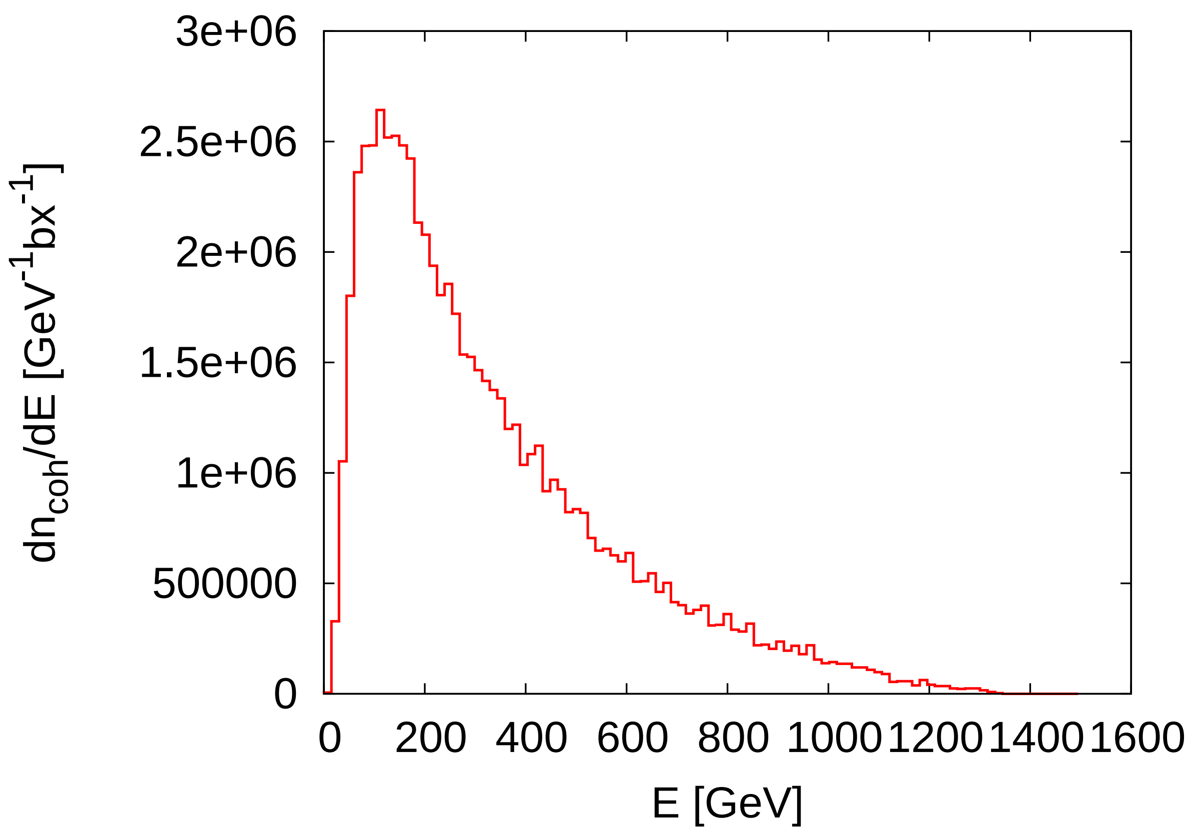
$\Rightarrow$ average energy loss is larger in CLIC than ILC

# Main Spent Beam Contents

- The beam particles are deflected by the beam-beam forces
- They radiate hard photons, the beamstrahlung
- In the strong beam fields beamstrahlung photons can turn into an electron positron pair
- Cross section depends exponentially on the field

⇒ Rate of pairs is small for centre-of-mass energies below $1\,\mathrm{TeV}$

⇒ In CLIC, rate is substantial

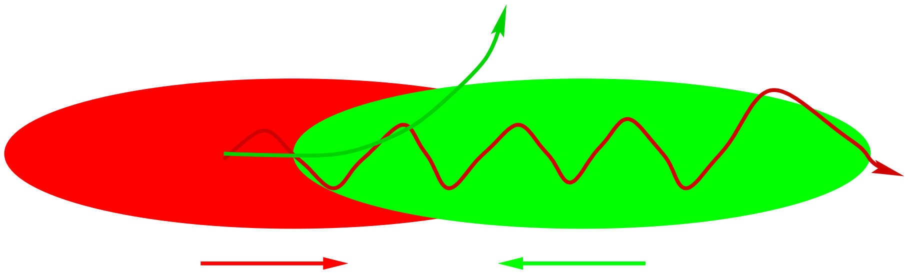


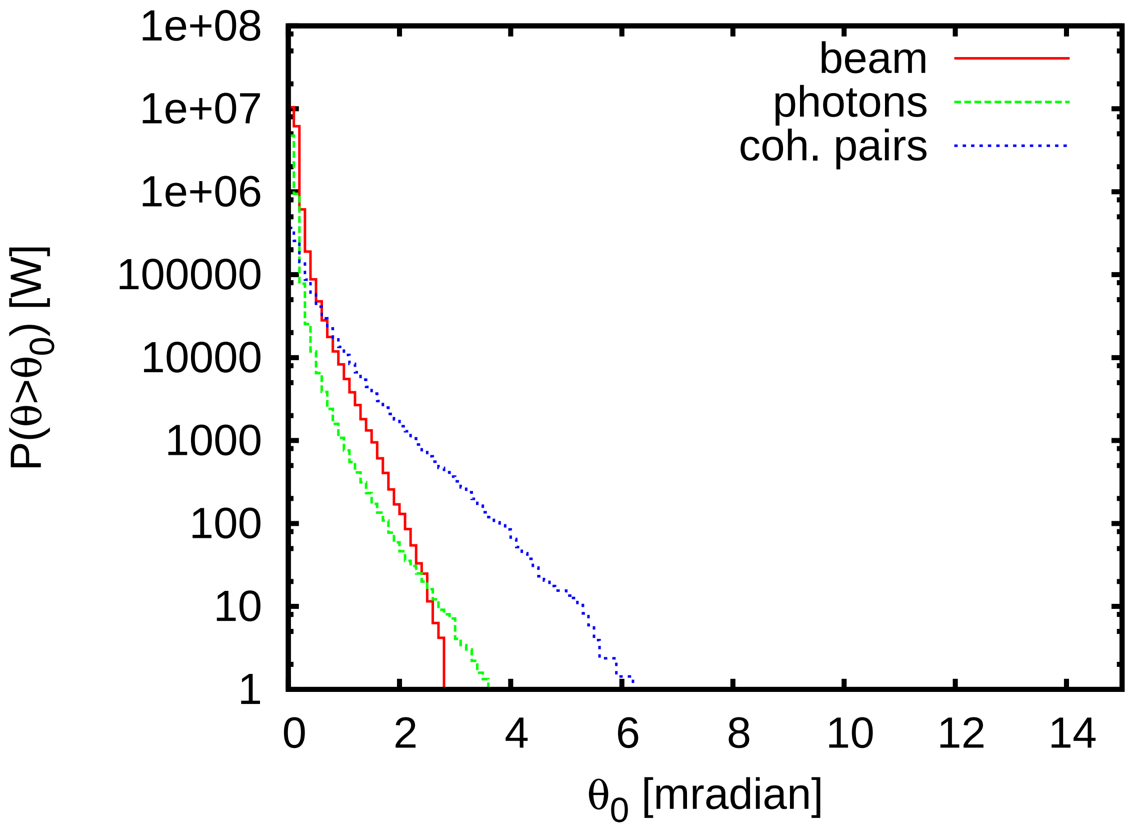
# Spent Beam Angular Distribution

- Beam particles are focused by oncoming beam
- Photons are radiated into direction of beam particles
- Coherent pair particles can be focused or defocused by the beams

$\Rightarrow$ Extraction hole angle should be significantly larger than $6\,\mathrm{mradian}$

$1\,\mathrm{W} \approx 400\,\mathrm{TeV/bx} \approx 300\,\mathrm{beamparticles/bx}$





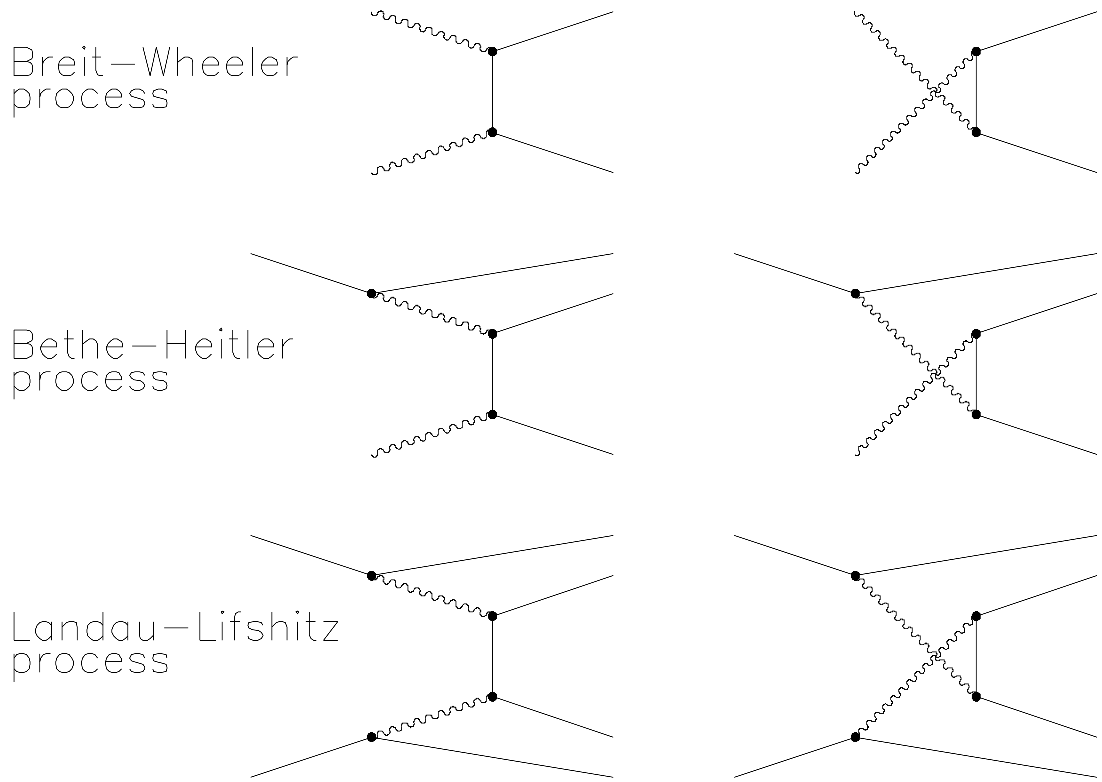
# Incoherent Pair Production

Three different processes are important

- Breit-Wheeler
- Bethe-Heitler
- Landau-Lifshitz

The real photons are beamstrahlung photons

The processes with virtual photons can be calculated using the equivalent photon approximation and the Breit-Wheeler cross section



# Deflection by the Beams

Most of the produced particles have small angles

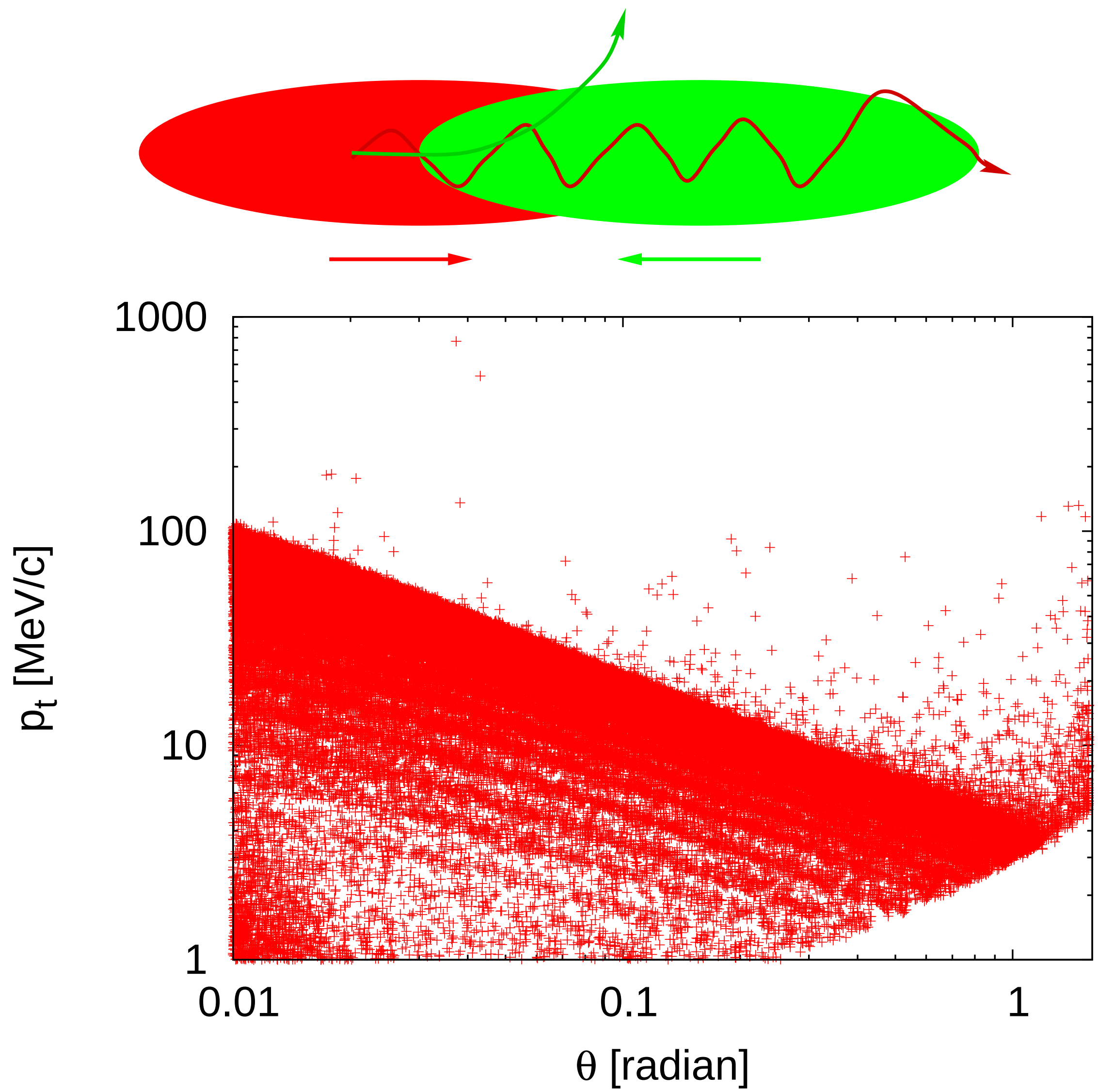
The forward or backward direction is random

The pairs are affected by the beam

$\Rightarrow$ some are focused some are defocused

Maximum deflection

$$\theta_m = \sqrt{4\frac{\ln\left(\frac{D}{\epsilon}+1\right) D\sigma_x^2}{\sqrt{3}\epsilon\sigma_z^2}}$$

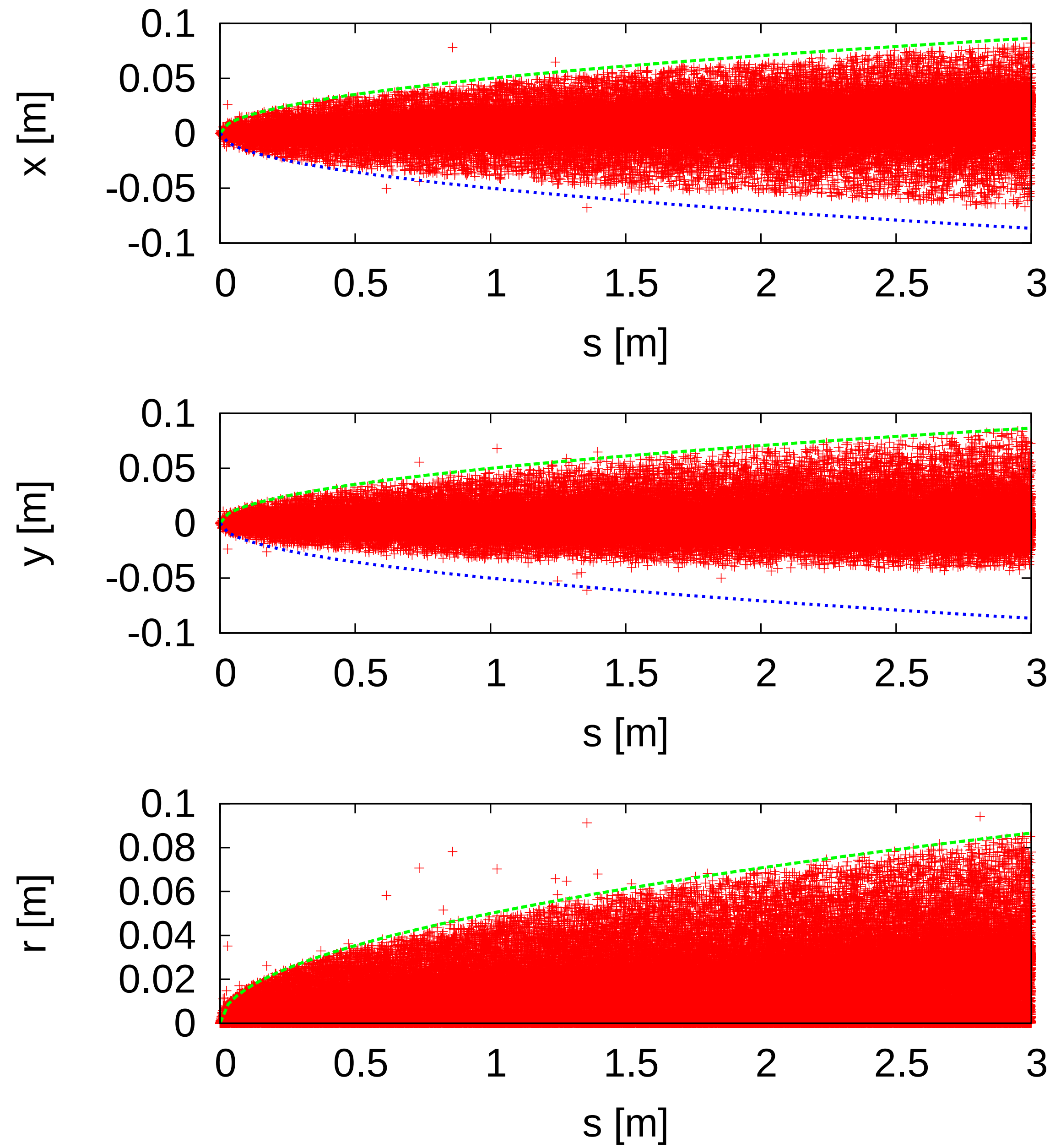


# Required Aperture

- Incoherent pairs are shown
  - deflection of coherent pairs is similar
  - but have higher energies, i.e. smaller angles
- Aperture requirement is roughly

$$r \approx 50\,\mathrm{mm}\sqrt{\frac{s}{\mathrm{m}}}$$

- Imperfections could increae this



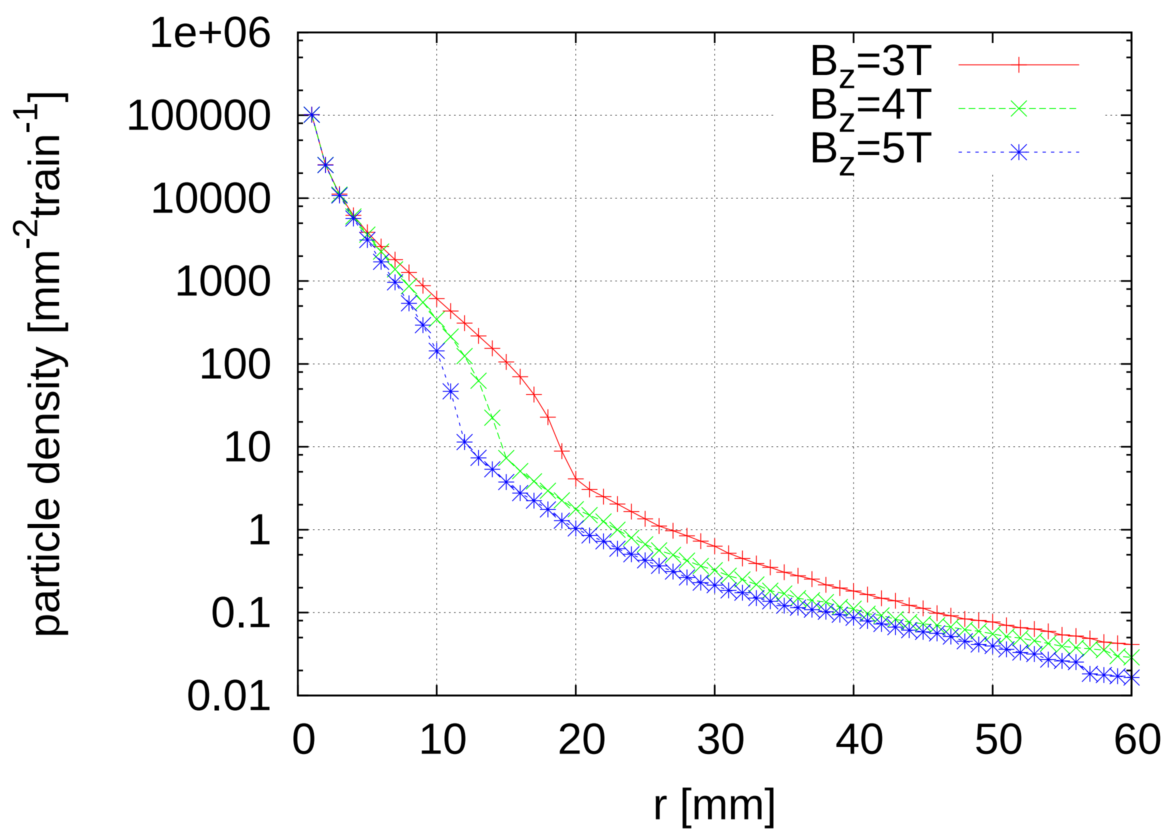
# Impact of the Incoherent Pairs on the Vertex Detector

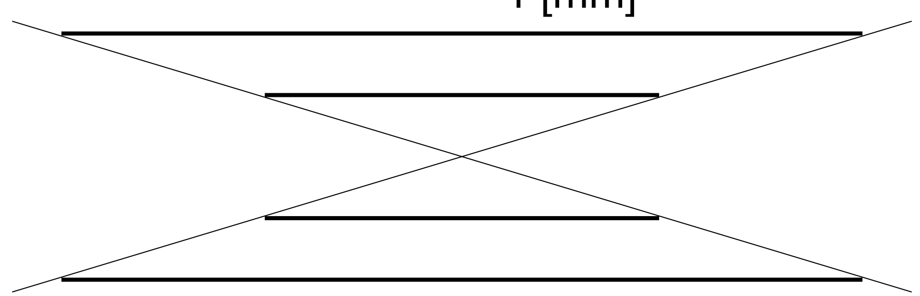
- Simplified study using simple cylinder without mass
  - coverage is down to $200\,\mathrm{mradian}$
- Simulating number of particles that hit at least once
  - experience indicates that number of hits is three per particle
  - but needs to be done with real detector parameters

⇒ At $r_1 \approx 30\,\mathrm{mm}$ expect 1 hit per train and $\mathrm{mm}^2$

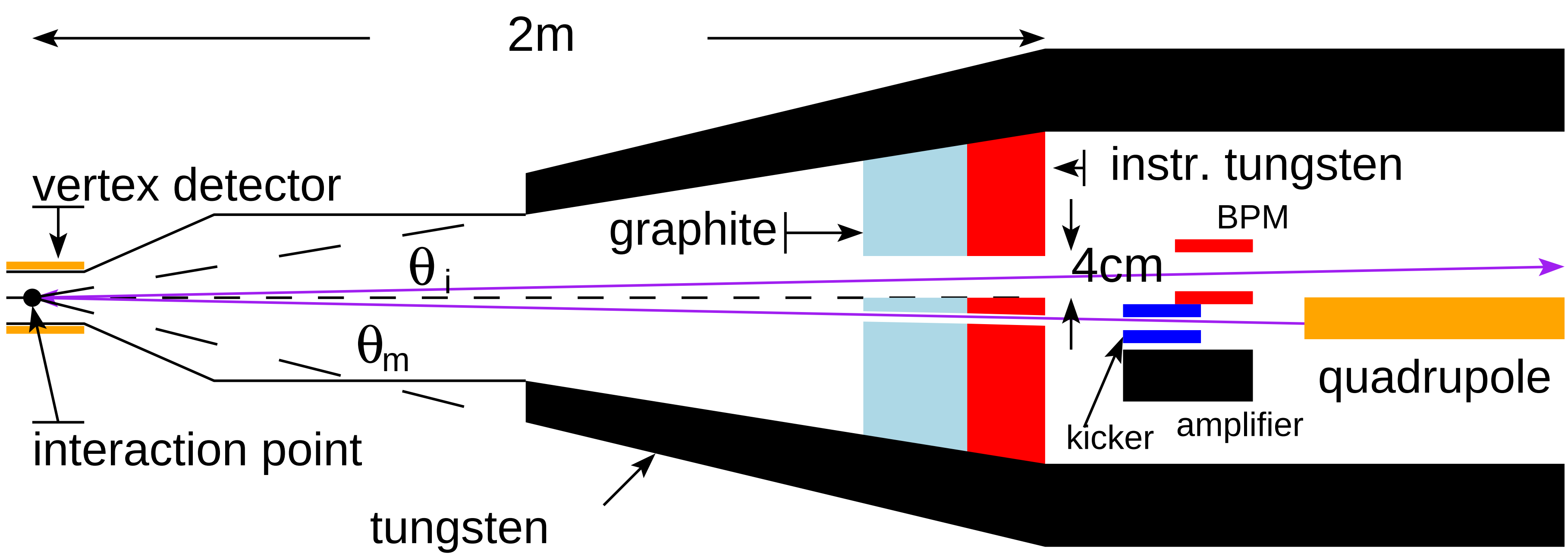
⇒ Detector should be a bit larger

  - but depends on technology



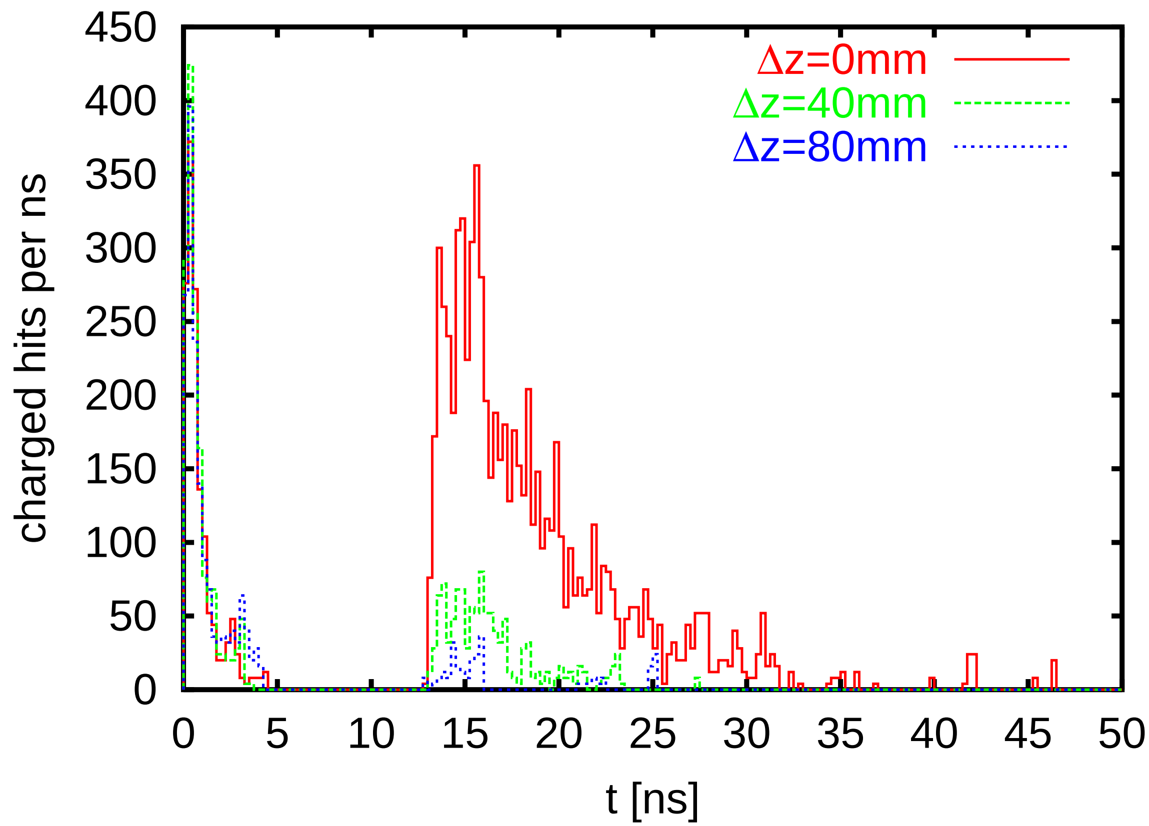
# Mask Design




- Current CLIC design corresponds to old TESLA design
  - improvement is possible
  - quadrupole can be further out
- Outer mask suppresses backscattered photons
  - maybe less coverage would be sufficient
- Inner mask prevents backscattering of charged particles
  - distance needs to be small enough that exit hole is smaller than vertex detector (neutrons)

# Inner Mask

- Low-Z material reduces backscattering
  - it allows electrons and positrons to penetrate with small probability of scattering
  - it reduces energy of backscattered charged particles via ionisation
- Required thickness is about $10\,\mathrm{cm}$



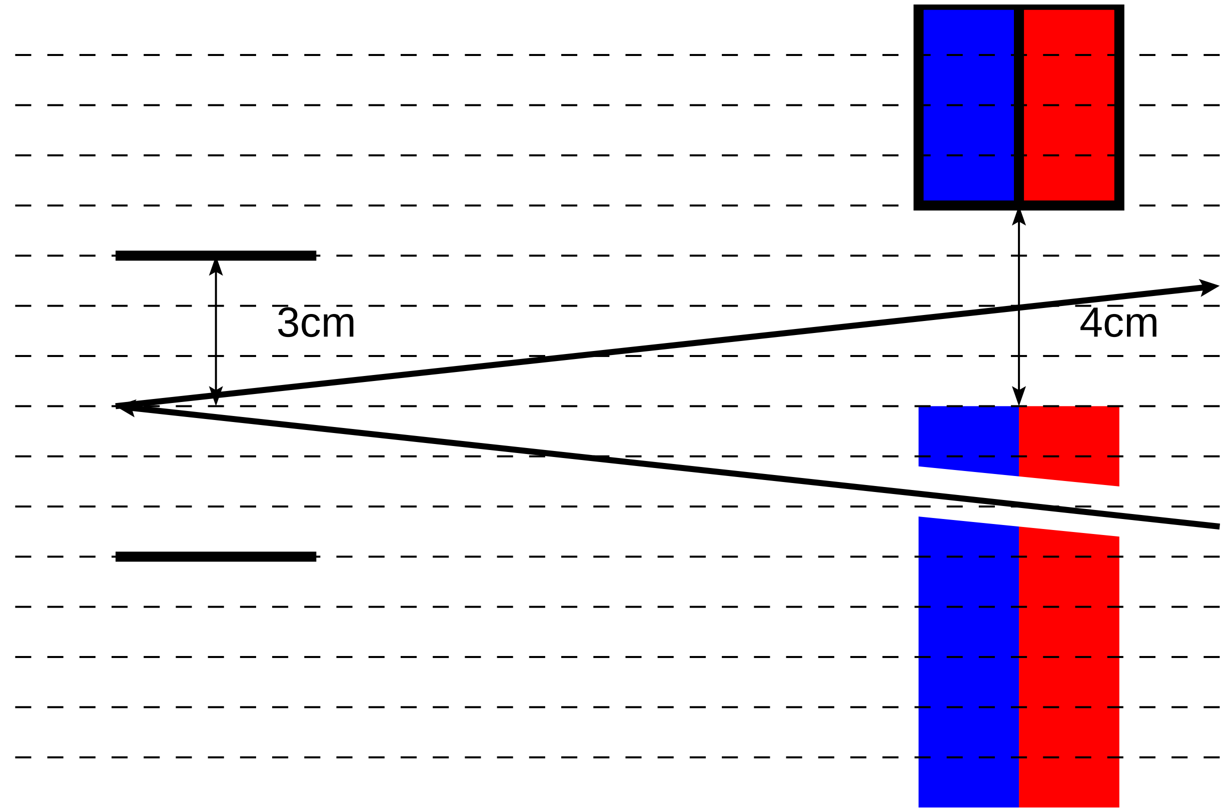

- But hole overlaps with vertex detector

$\Rightarrow$ could have backscattering through the hole, if not careful

# Backscattering Scheme

- Magnetic field lines may guide low energy particles back through exit hole into vertex detector layer

  ⇒ need to prevent backscattering also behind inner mask



# Luminosity Tuning Signal

- Luminosity signal
  - radiative Bhabhas appear slow

$$\frac{d\sigma}{dt} = \frac{2\pi m^2 r_e^2}{s^2}\left[\frac{s^2+u^2}{t^2}+\frac{2u^2}{ts}+\frac{u^2+t^2}{s^2}\right]$$

  - at agressive $\geq 10\,\mathrm{mradian}$ rate of $\mathcal{O}(20Hz)$
  - at safer $\geq 30\,\mathrm{mradian}$ rate of $\mathcal{O}(2Hz)$

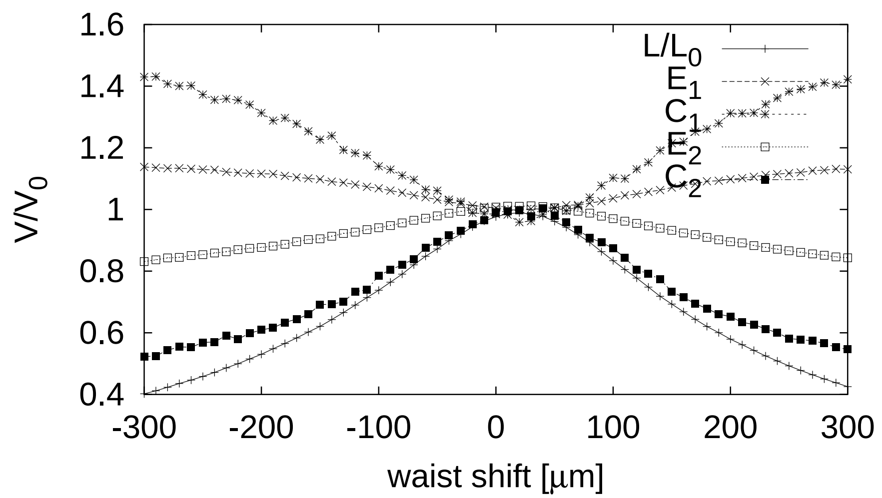
  $\Rightarrow$ need $7\text{–}70\,\mathrm{minutes}$ for 1% luminosity measurement

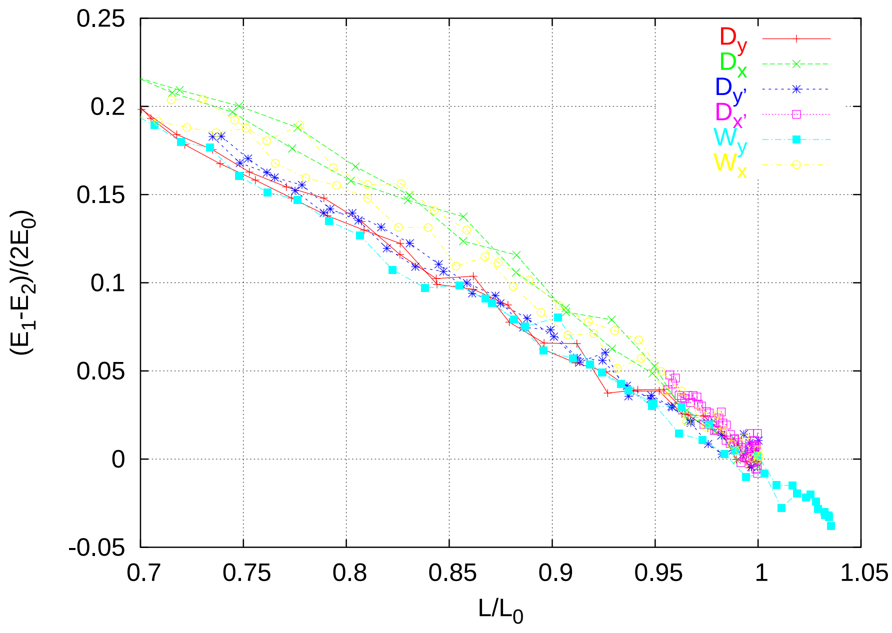
  - but luminosity is precise to 1% in $2\,\mathrm{s}$
- Other signals can be used to tune knobs
- Good candidate is beamstrahlung

$\Rightarrow$ Post collision line instrumentation is critical

$\Rightarrow$ Tuning simulations with realistic signals are important

  - systematic effects could be important



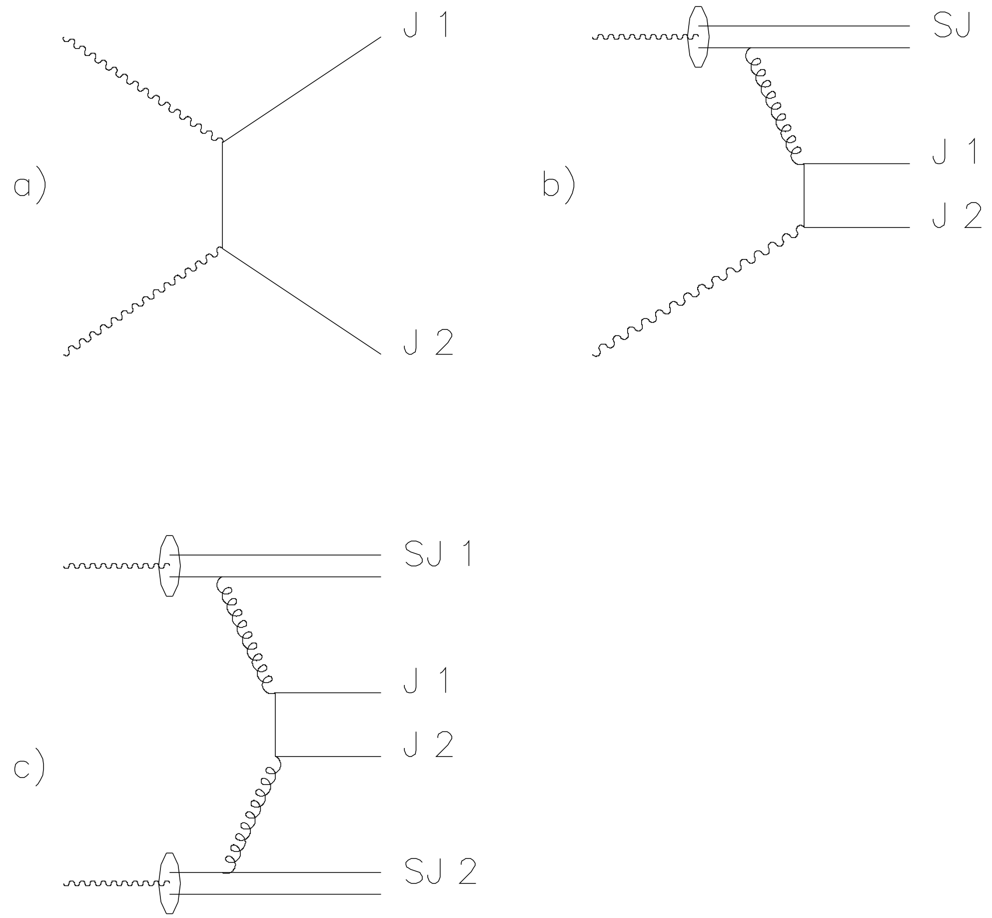
# Hadronic Background

A photon can contribute to hadron production in two ways

- direct production, the photon is a real photon
- resolved production, the photon is a bag full of partons

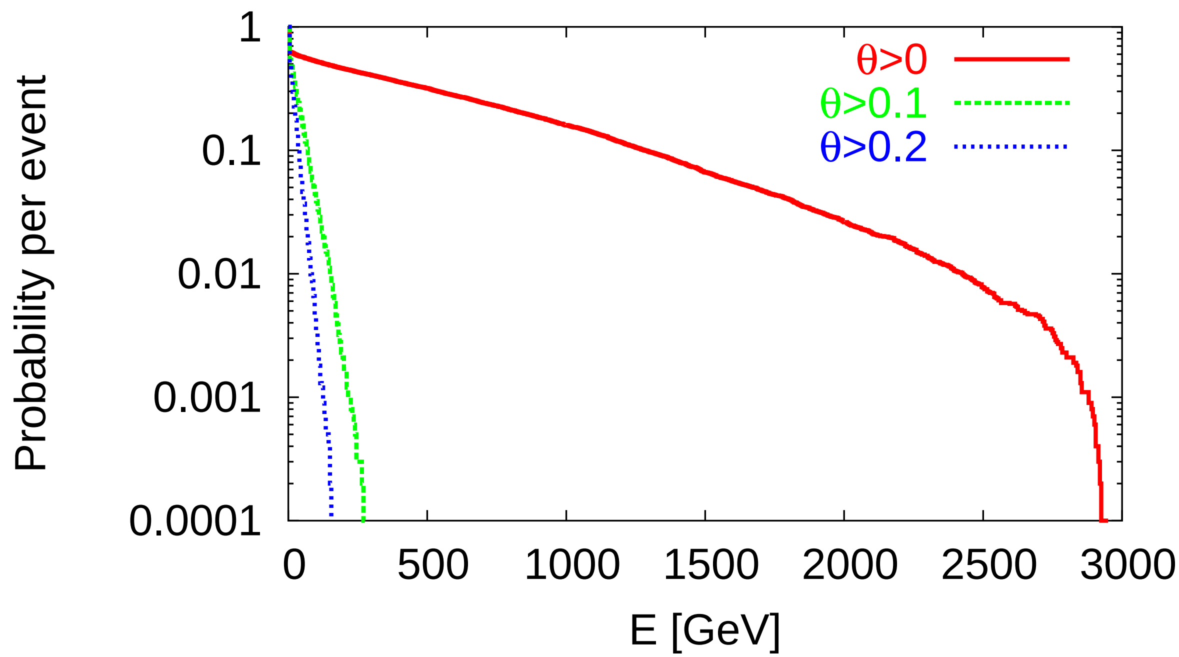
Hard and soft events exist

e.g. “minijets”



# Hadronic Events

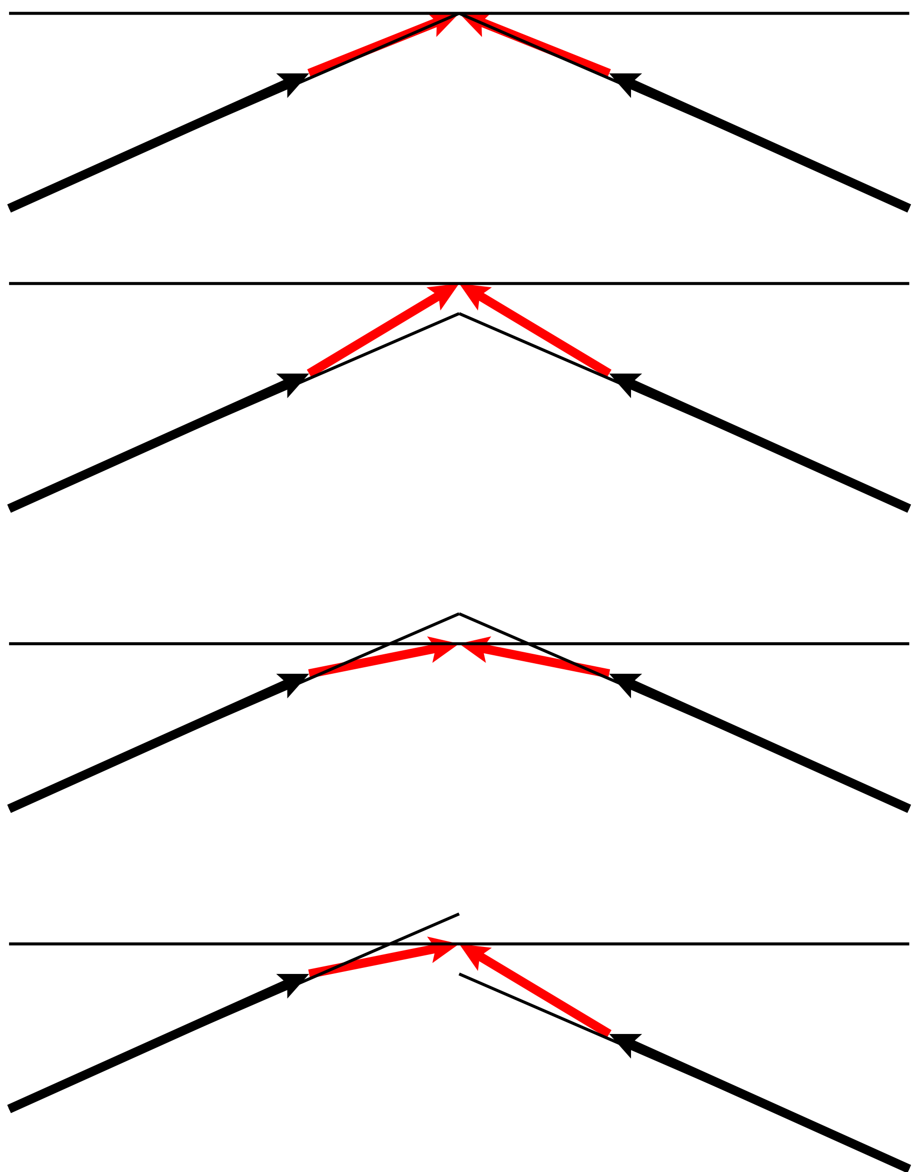
- Hadronic events with $W_{\gamma\gamma} \geq 5\,\mathrm{GeV}$
- Most energy is in forward/backward direction
  - $E_{vis} \approx 450\,\mathrm{GeV}$ per hadronic event for no cut
  - $E_{vis} \approx 23\,\mathrm{GeV}$ for $\theta > 0.1$
  - $E_{vis} \approx 12\,\mathrm{GeV}$ for $\theta > 0.2$
  - 20% from $e^+e^-$ (cannot be reduced)




- Charged tracks from hadronic events add about 20% to the charged hits in the vertex detector
- Secondary nuetron flux can be noticeable

# Crossing Angle Comments

- Crossing angle between linacs needs to be fixed
- Beam delivery system has non-zero bend angle ($\approx 0.6\,\mathrm{mradian}$)
- Four main options exist
- Would prefer to adjust collision angle
  - optimisations may change BDS angle
- Suggestion: prepare for 20 $\mathrm{mradian}$ but be flexible to be able to reduce this
- Would a small modification of crossing angle be acceptable for the detector?



# Conclusion

- We prefer a crossing angle of $20\,\mathrm{mradian}$
  - would be nice to have flexibility for small reductions
- An intra-pulse interaction point feedback is helpful
  - but needs to be very to the IP
  - quadrupole stability requirements remain tight
- Need a support for the final quadrupoles
  - space requirements to be worked out
- Masking system needs critical review
- Need to design detector field around the incoming beam line