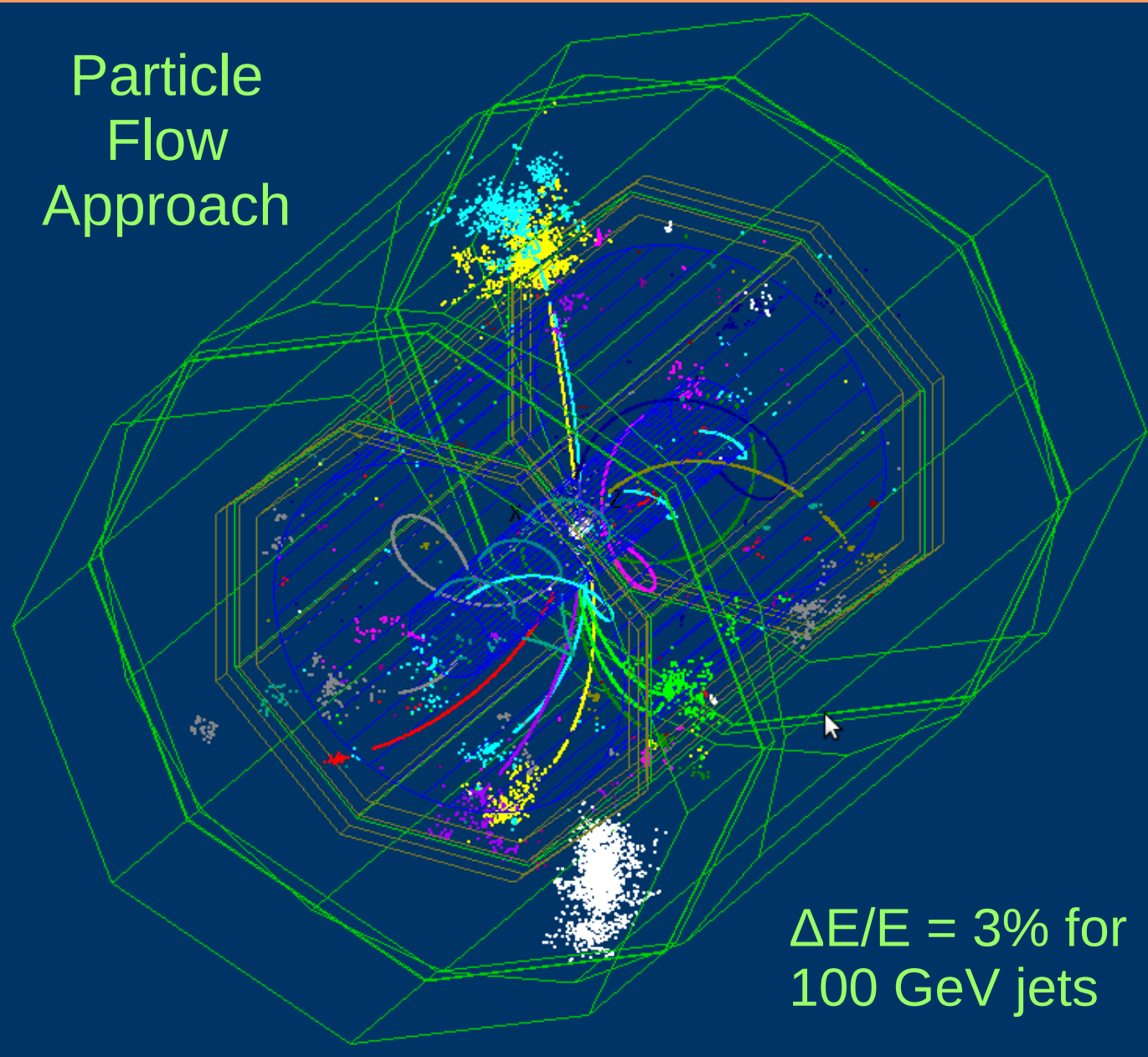


# Backgrounds at future $e^+e^-$ colliders

Particle  
Flow  
Approach



$\Delta E/E = 3\%$  for  
100 GeV jets

Major  
contributors:

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# International Linear Collider (ILC)



**30 MV/m**

500 (up to 1000) GeV, 31 km

2625 bunch crossings (BX)



# Compact Linear Collider (CLIC)



**80 MV/m**

500 (up to 3000) GeV, 13 (48) km

354 BX



**Drive beam**

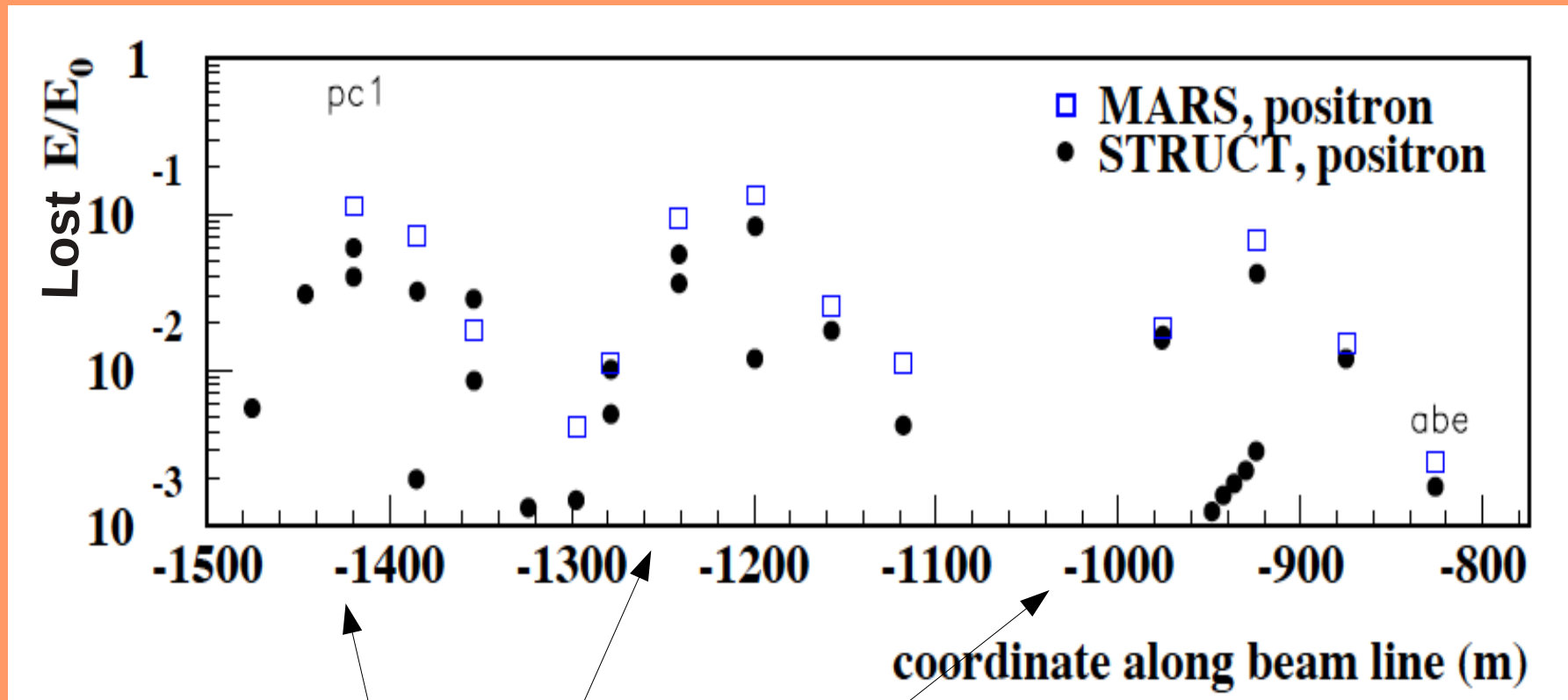
# Machine-related backgrounds



## Beam delivery system

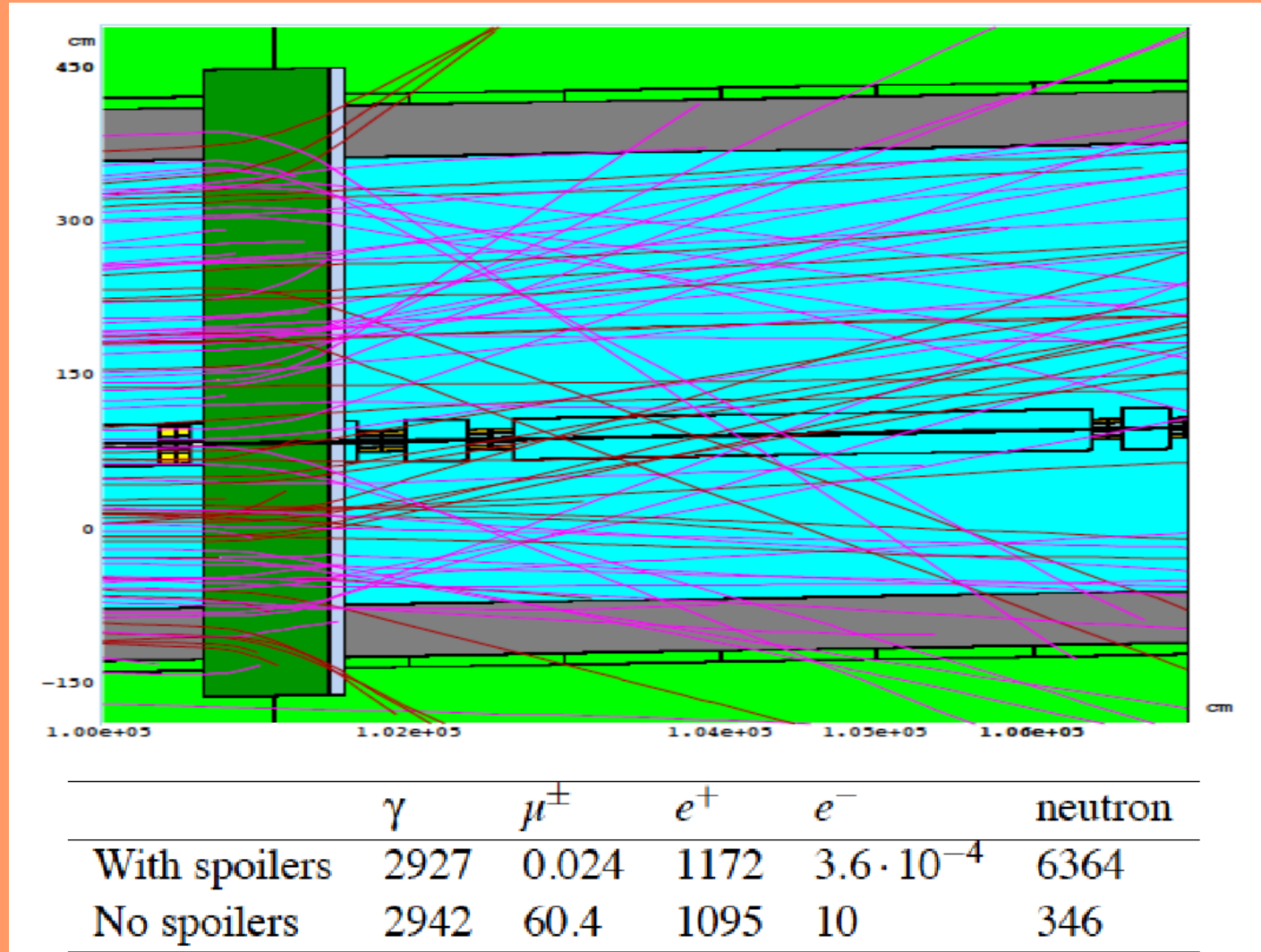
- Muons and antimuons  
(from showers)
- Hard photons
- Neutrons  
(from photo-nuclear reactions)
- Off-energy electrons and positrons

Presence of collimators leads to conversion of beam particles to  $e^+e^-$ ,  $\mu^+\mu^-$ ,  $\gamma$  and  $n$ .



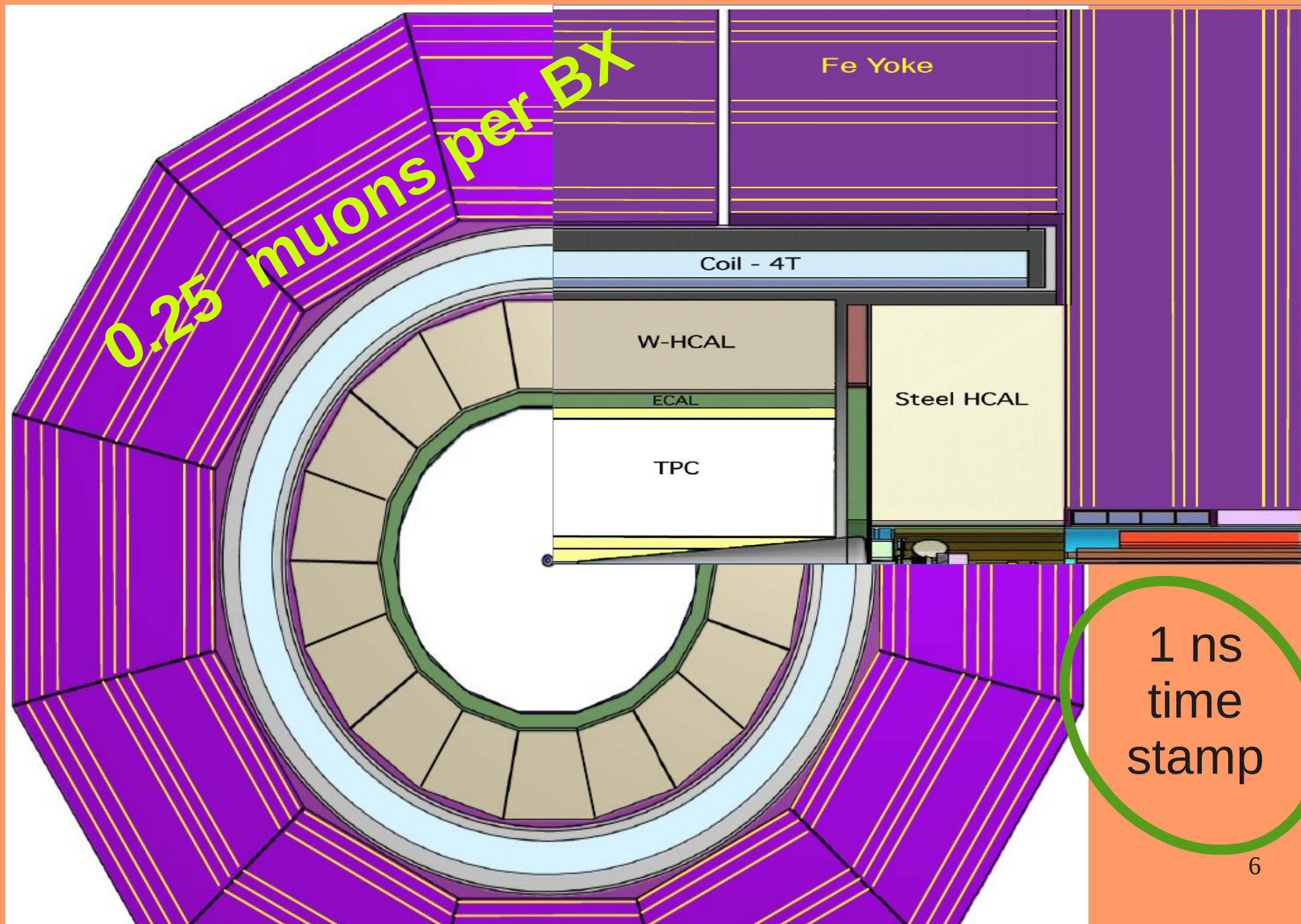
Positions of collimators

# Muons can be swept away by spoilers, but at the cost of more neutrons





# Muons in the CLIC detector



# International Linear Collider (ILC)



**30 MV/m**

500 (up to 1000) GeV, 31 km  
 $L = 2 \times 10^{34} / \text{cm}^2 \text{s}$ , beam 650 x 6 nm

2625 bunch crossings (BX)



# Compact Linear Collider (CLIC)



**80 MV/m**

500 (up to 3000) GeV, 13 (48) km  
 $L = 2.3 \times 10^{34} / \text{cm}^2 \text{s}$ , beam 200 x 2 nm

354 BX



**Drive beam**

# Machine-related backgrounds



## Beam delivery system

- Muon and antimuons (from showers)
- Hard photons
- Neutrons (from photo-nuclear reactions)
- Off-energy electron and positrons

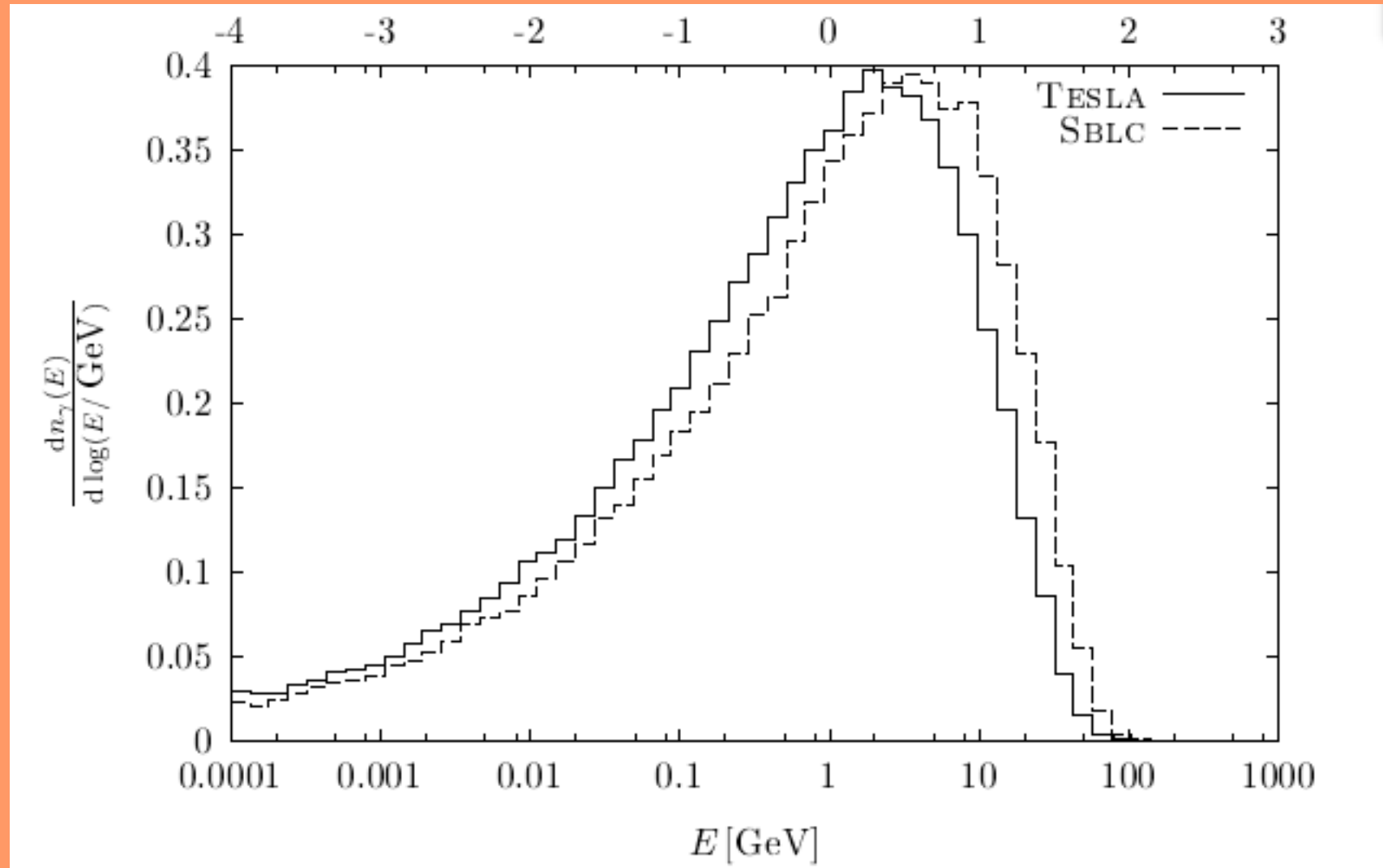


## Interaction point

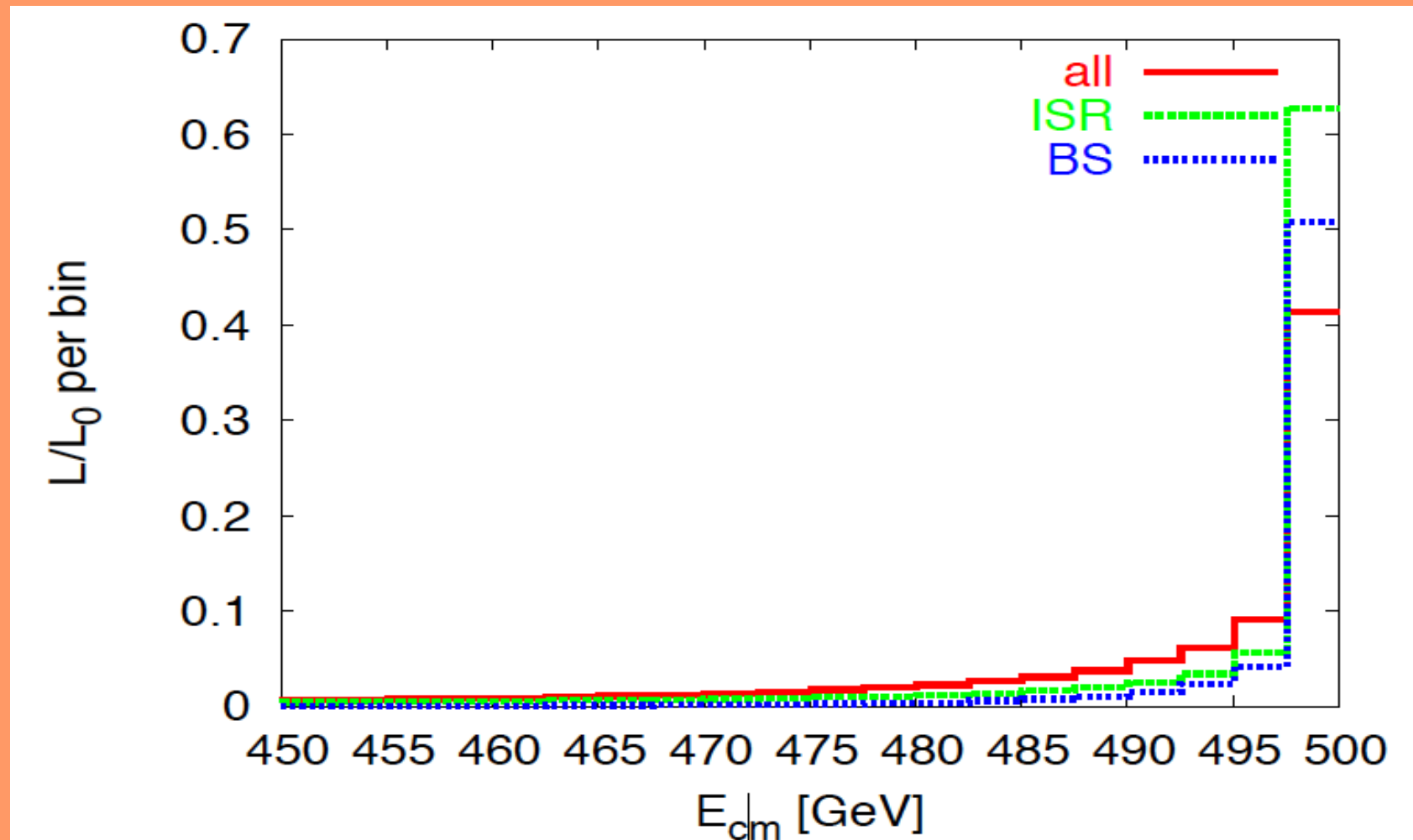
- Beamstrahlung
- Radiative Bhabha scattering



# Beamstrahlung: opposite bunches focus each other, emitting photons

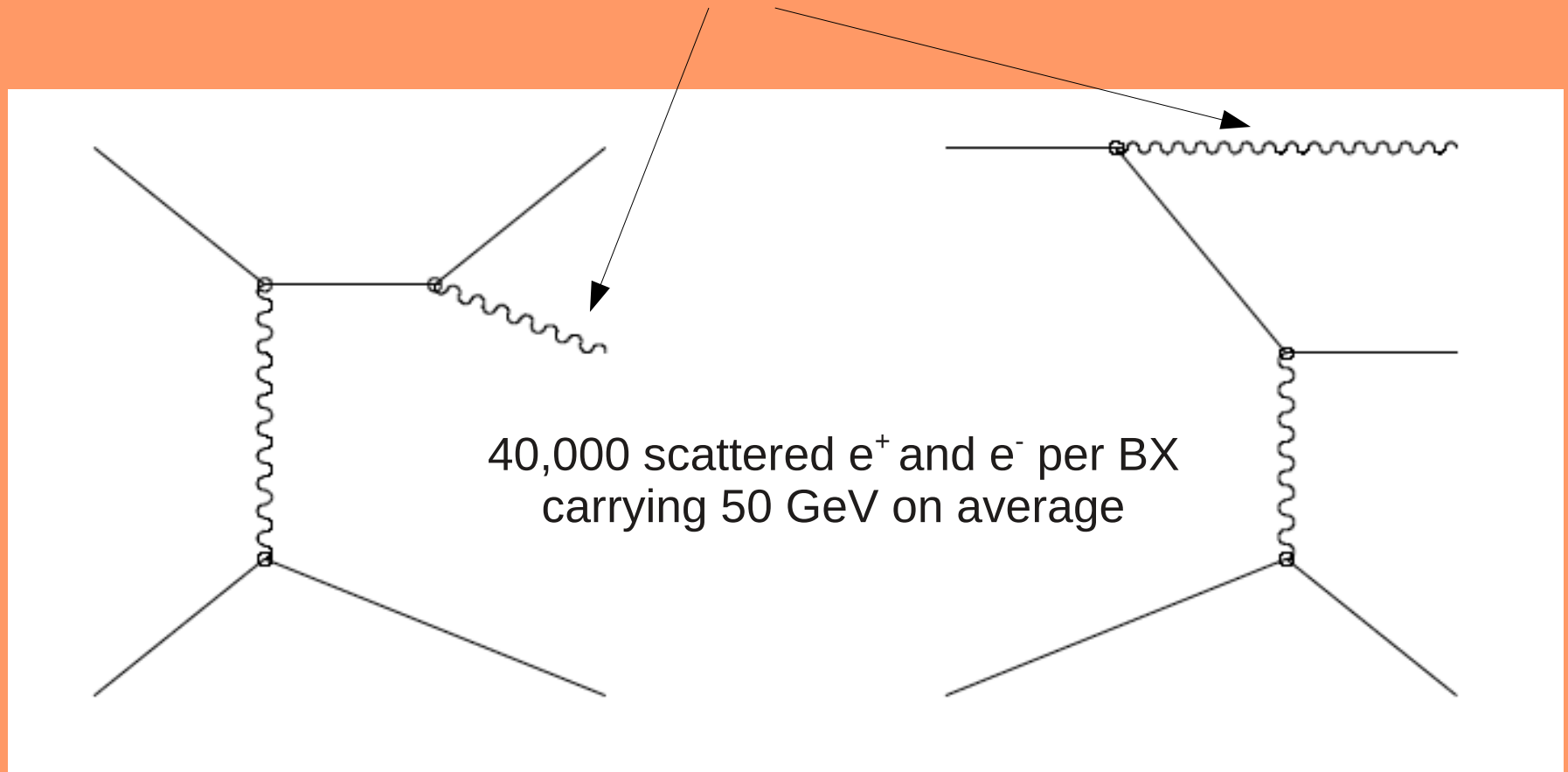


# Both beamstrahlung and initial state radiation reduce luminosity

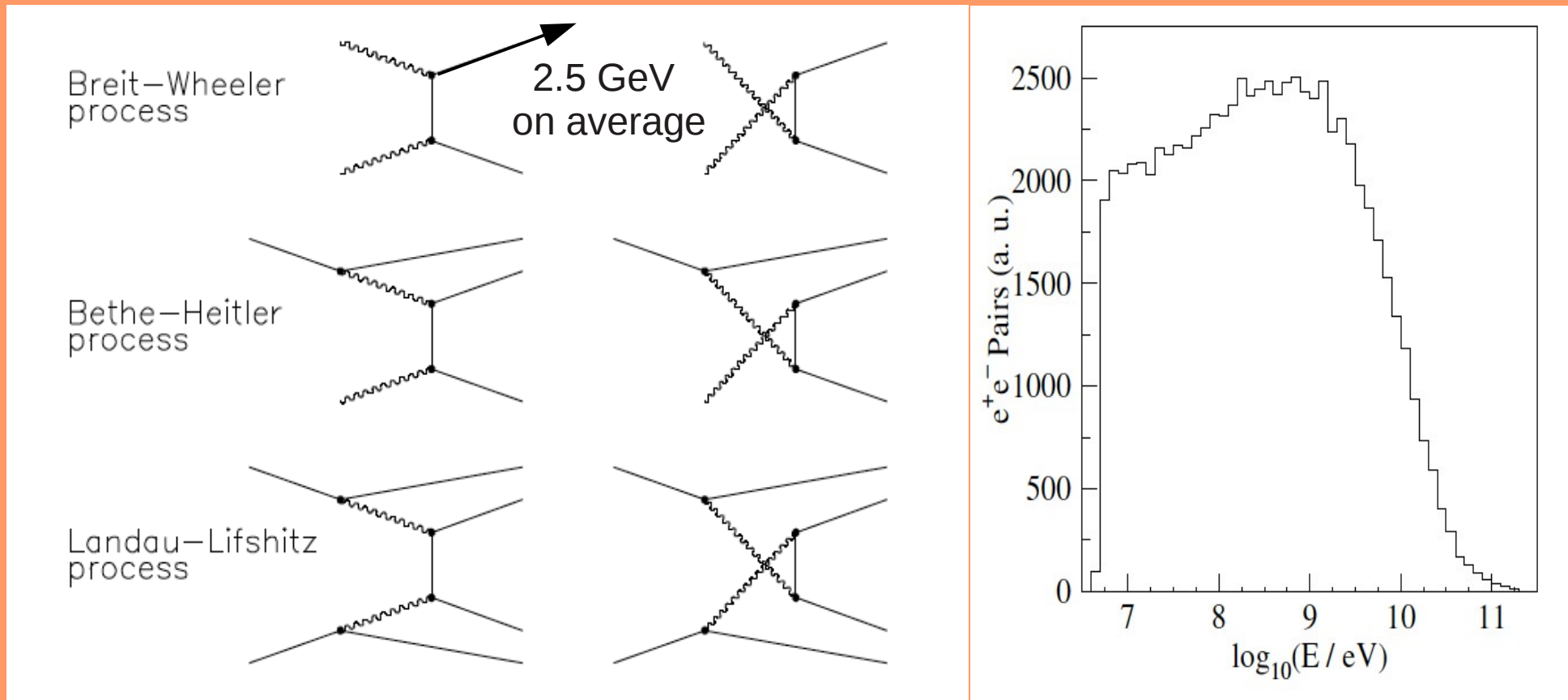


# Radiative Bhabha scattering is one more source of hard photons at ILC

Photons move along beams and escape through beam pipe



# Incoherent pair production at ILC: 76,000 pairs per BX



At CLIC, the **coherent** pair production dominates: photon + field

# Soft electrons and positrons lead to observable background

Bhabha  
electrons/positrons

Beamstrahlung pairs

Focused  
along beams

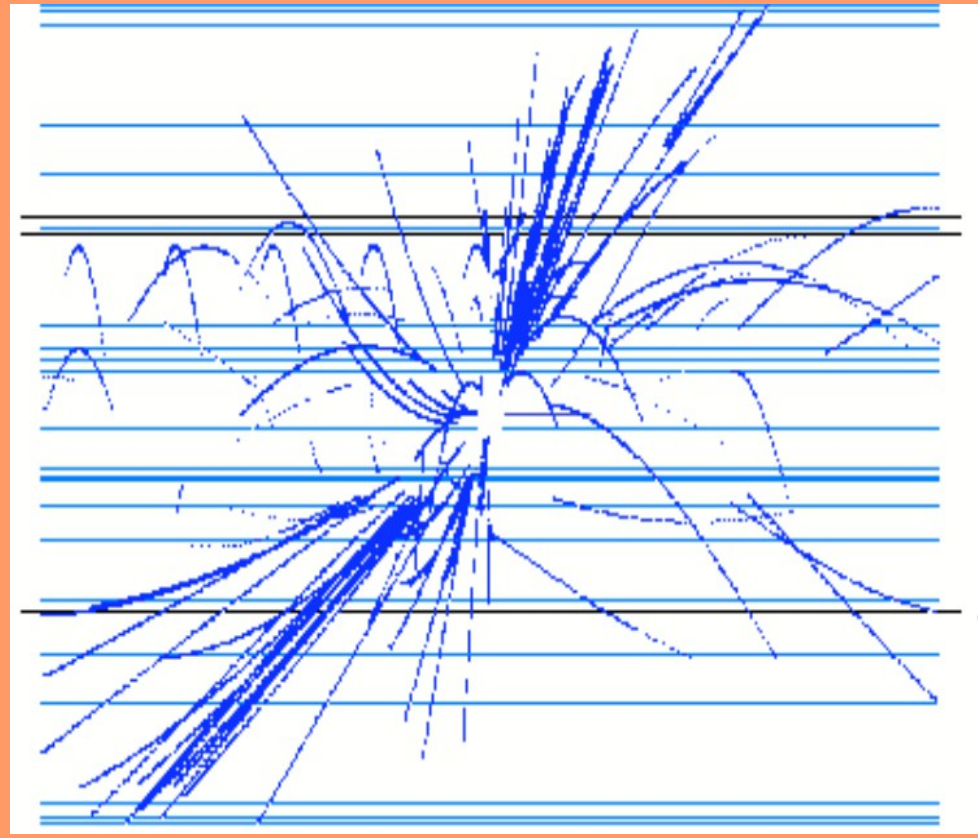
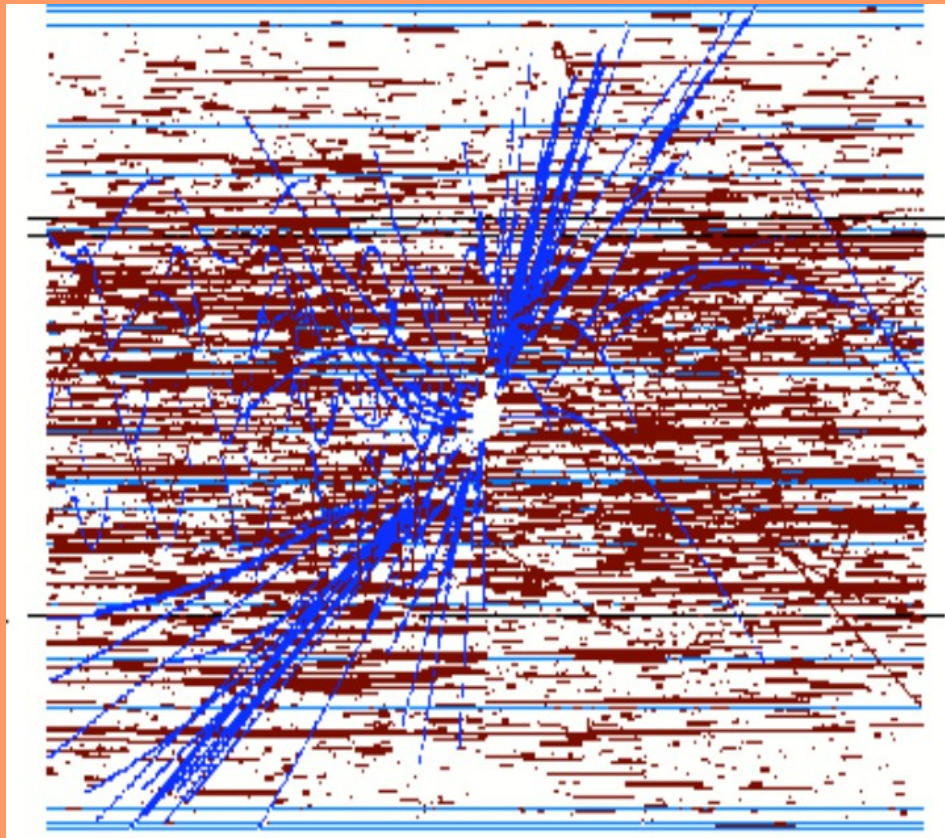
High  $p_t$

Low  $p_t$

Curl up and move longitudinally,  
hitting innermost detectors,  
beam pipe and magnets

# Beamstrahlung-produced electrons and positrons in the ILC tracker

Removed by software





# Soft electrons and positrons lead to observable background

Bhabha  
electrons/positrons

Beamstrahlung pairs

Focused  
along beams

High  $p_t$

Low  $p_t$

Curl up and move longitudinally,  
hitting innermost detectors,  
beam pipe and magnets

Produce showers: photons and secondary pairs

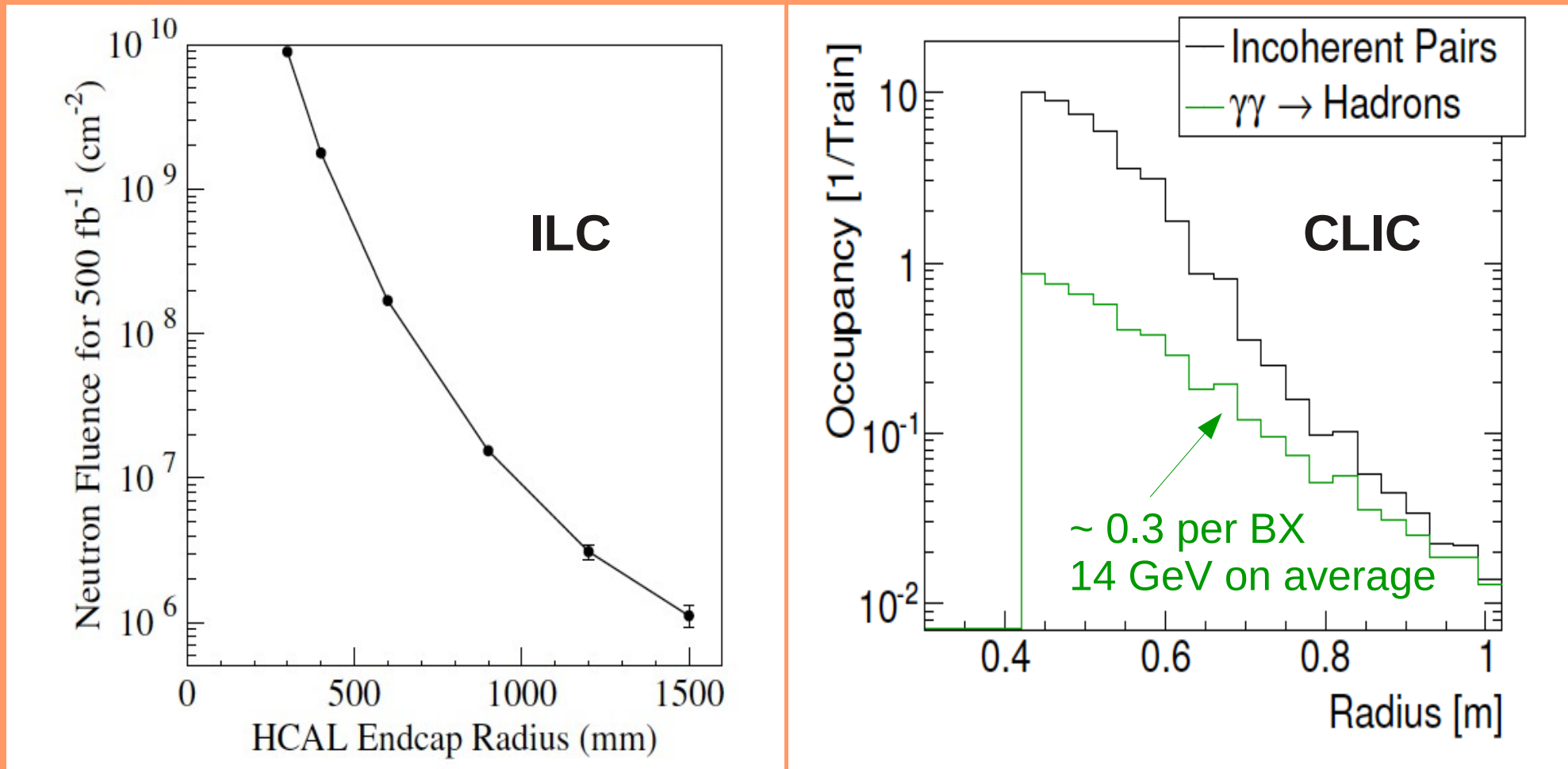
70,000 per BX

Dumping in magnets

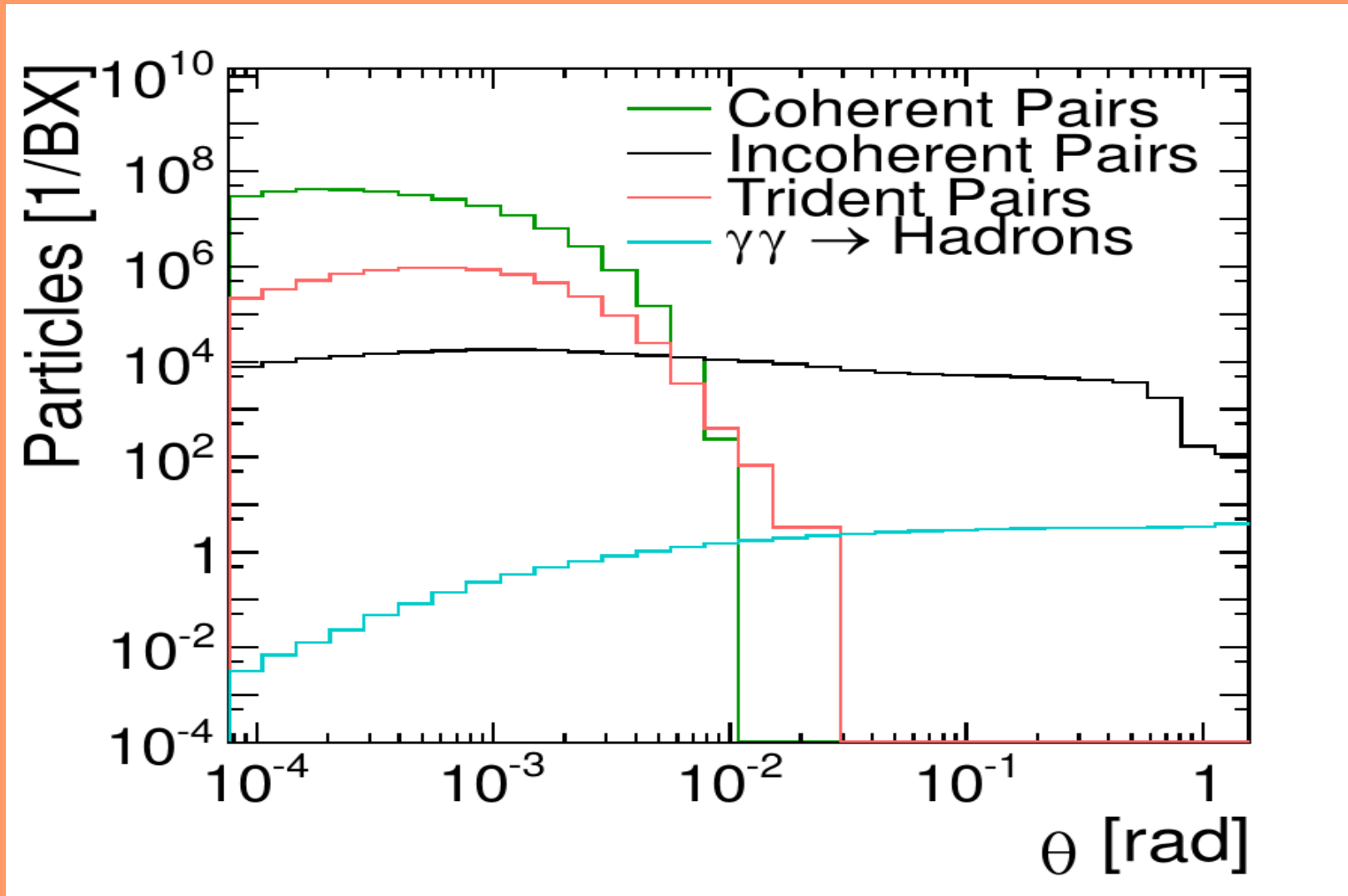
500,000 per BX

Neutrons from photonuclear reactions:  
resonance at 10 MeV photons

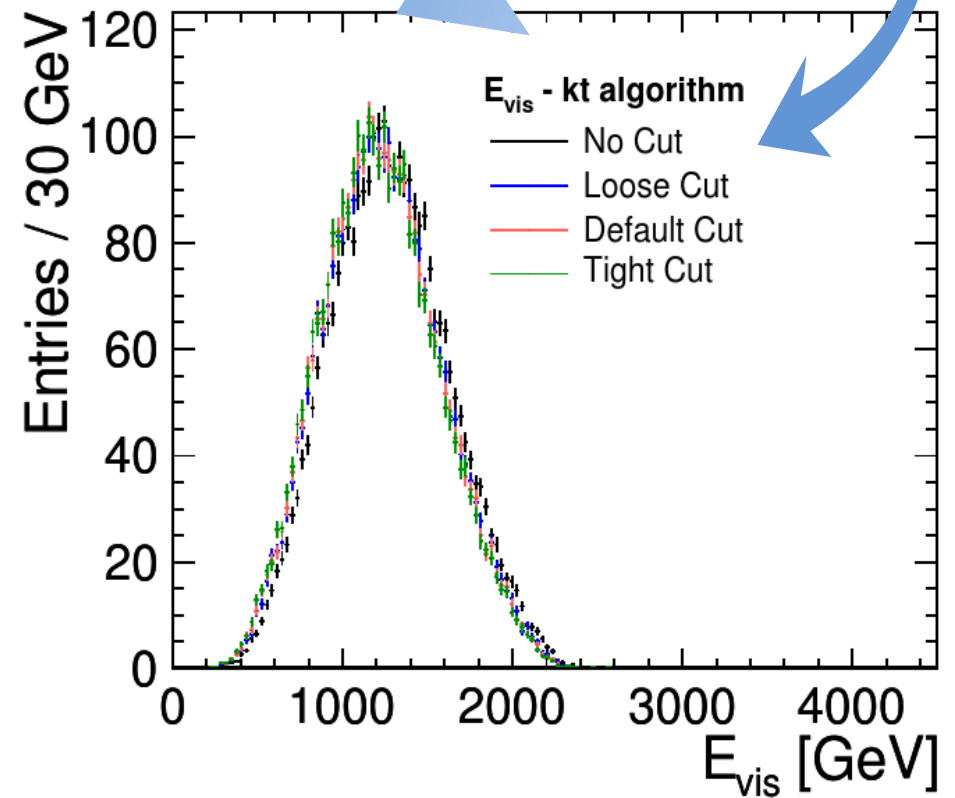
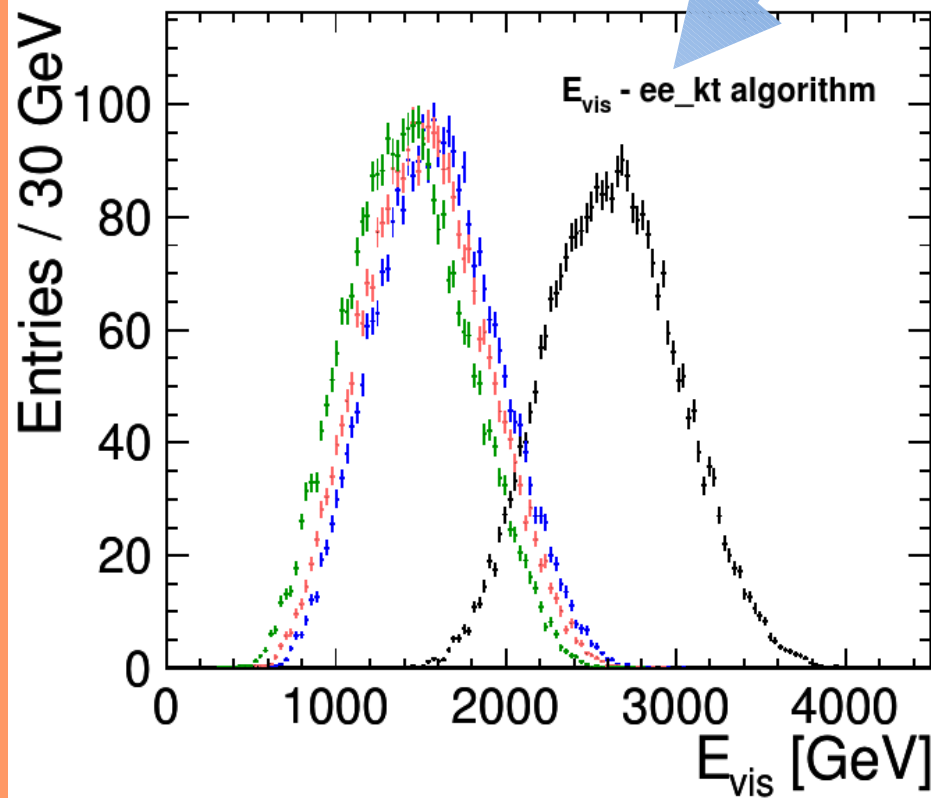
# Occupancy of hadronic calorimeter endcaps by background signals



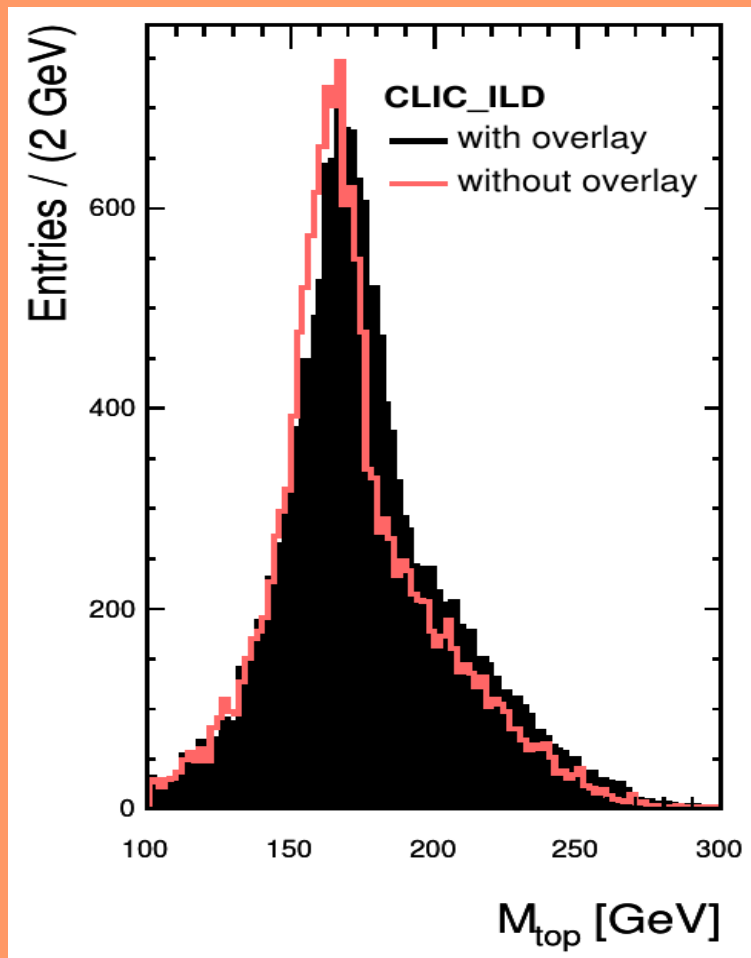
# Angular distribution of background particles at the 3 TeV CLIC



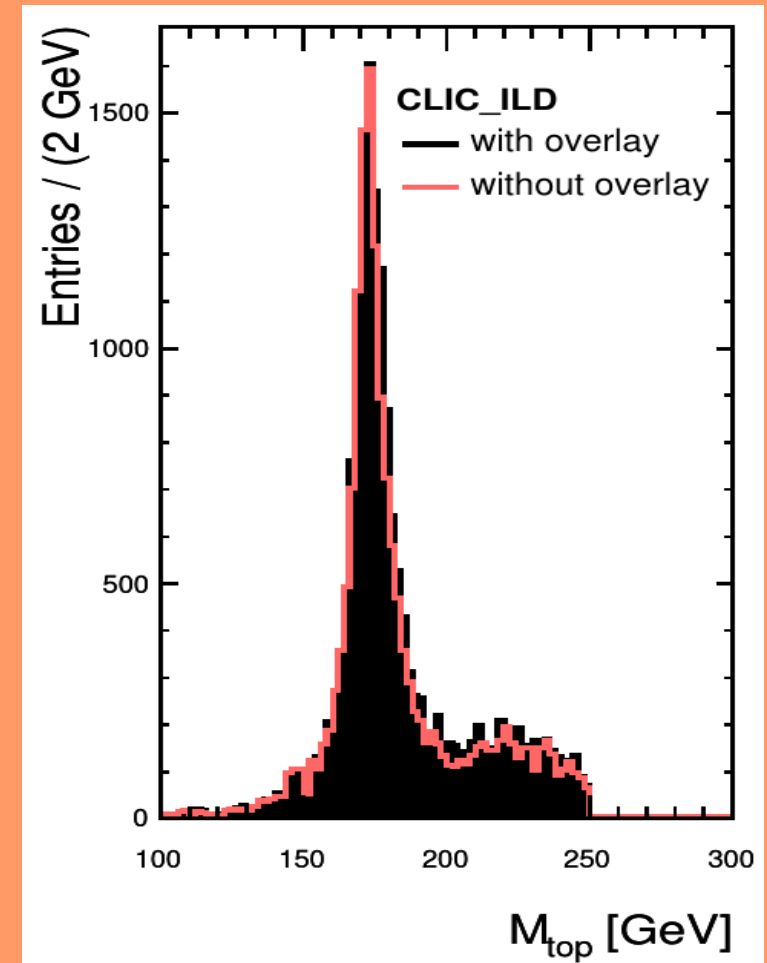
# Energy of a benchmark reconstructed with different jet-finders and time cuts



# Top mass reconstructed with/without $\gamma\gamma \rightarrow \text{hadrons}$ background overlay



Kinematic  
fit  
technique



# Summary

- Both high collision energy and luminosity of future linear  $e^+e^-$  colliders lead to unprecedented beam-related backgrounds
- Background muons load the muon system of detector and should be coped with by a precise time resolution and appropriate system design
- Signals of  $e^+e^-$ -pairs produced by beamstrahlung photons in tracker can be removed by software
- Background neutrons only load calorimeter's endcaps
- Hadrons from mini-jets produced by beamstrahlung photons contribute to background in the entire electromagnetic calorimeter, but can be rejected by time cuts and by an appropriate jet-finder