CLIC IR Overview

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- Quick overview of IR issues
- Activity in the area has been limited recently
  - BDS lattice design
  - collimation system
  - post collision line
- Activity on MDI and technical beam line components is (re-)starting at CERN

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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}	[Hz]	100	50	50	100	5	120
n_b		312	312	312	154	2820	190
σ_x	$[nm]$	115	81	40	40	655	243
σ_y	$[nm]$	2	1.4	1	1	5.7	3
Δt	$[ns]$	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
ϵ_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_γ		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	37.0	3.8×10^3	?	—	—
E_{coh}	$10^3 TeV$	0.5	1080	2.6×10^5	?	—	—
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

- Note: low energy CLIC parameters just an illustration

Luminosity and Luminosity Spectrum

- Four main sources of energy spread at the IP

  - initial state radiation

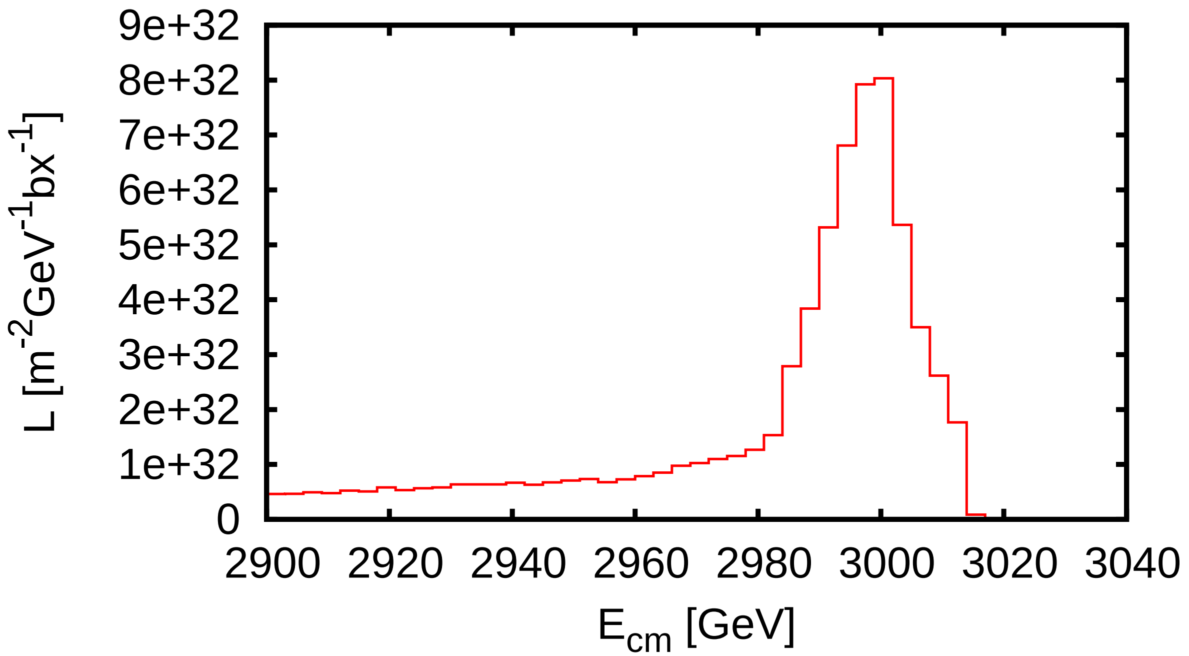
    ⇒ unavoidable

    ⇒ has sharp peak

  - beamstrahlung

    ⇒ similar shape as ISR

    ⇒ can be reduced by reducing luminosity



- single bunch energy spread

  due to single-bunch beam loading and RF curvature

  ⇒ part cannot be avoided

  ⇒ helps in stabilising the linac

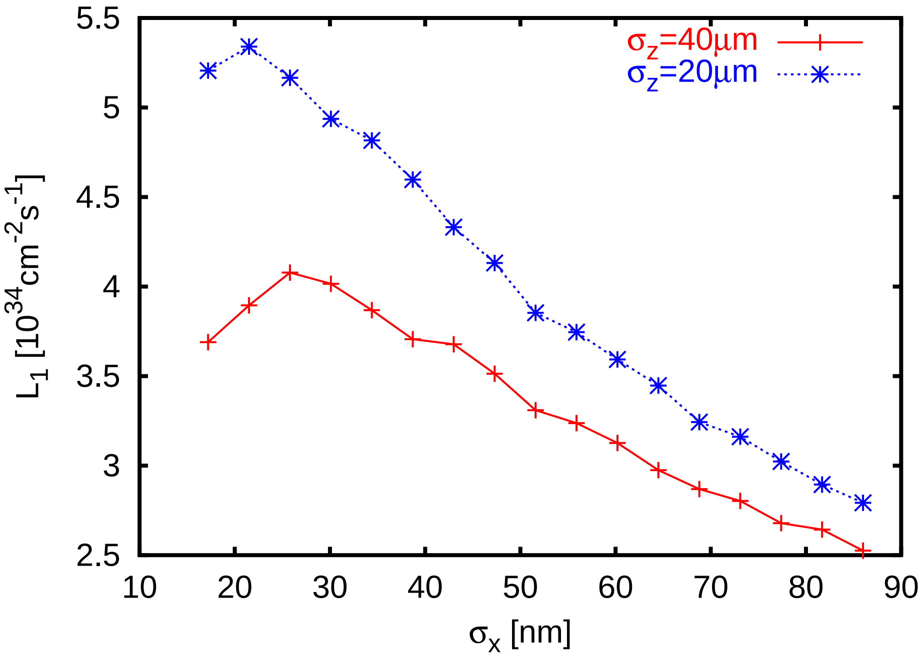
  ⇒ $\mathcal{O}(1\,\%)$ (better for ILC)

  ⇒ now included in simulation

- bunch-to-bunch and pulse-to-pulse variations

  ⇒ $\mathcal{O}(0.1\,\%)$

Beamstrahlung and Luminosity Optimisation

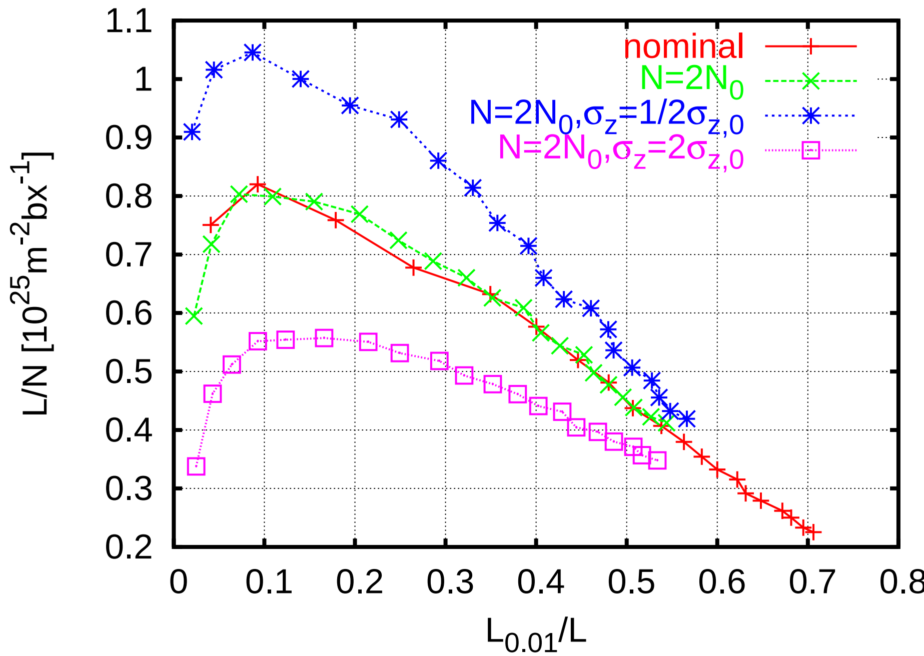


Total luminosity for $\Upsilon \gg 1$

$$\mathcal{L} \propto \frac{N}{\sigma_x}\frac{\eta}{\sigma_y} \propto \frac{n_\gamma^{3/2}}{\sqrt{\sigma_z}}\frac{\eta}{\sigma_y}$$

large n_γ ⇒ higher $\mathcal{L}$ ⇒ degraded spectrum

$$\mathcal{L}_{0.01} \propto \frac{(1-\exp(-n_\gamma))^2}{\sqrt{n_\gamma}}\frac{\eta}{\sqrt{\sigma_z}\sigma_y}$$



chose n_γ, e.g. maximum $L_{0.01}$ or $L_{0.01}/L = 0.4$ or . . .

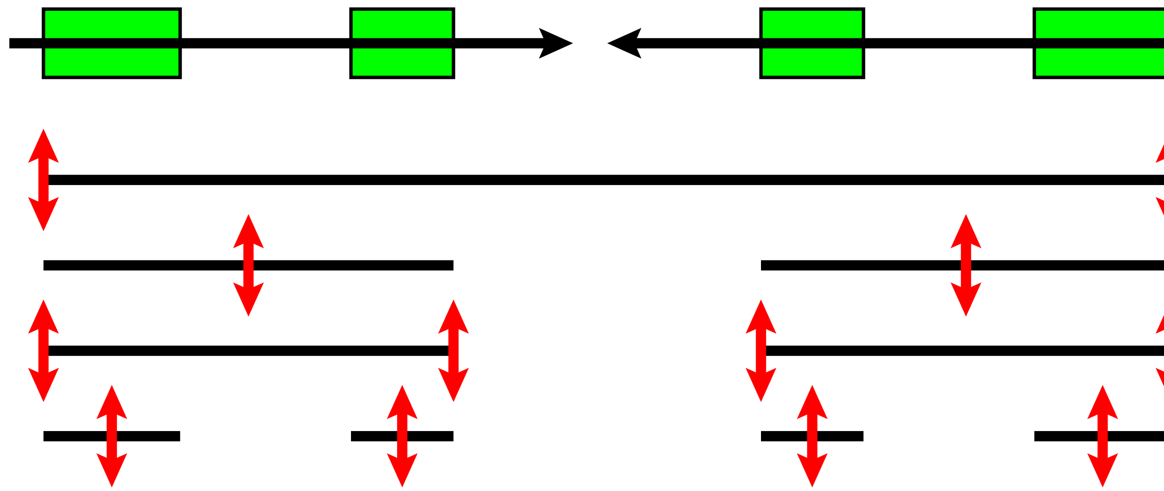
$$\mathcal{L}_{0.01} \propto \frac{\eta}{\sqrt{\sigma_z}\sigma_y}$$

Final Doublet Jitter

- One support structure
  - relative tolerance on end points ≈ 4–$5\sigma_{beam-beam}$
- Two support structures
  - relative tolerance of mid points $\approx 0.7\sigma_{beam-beam}$
  - relative tolerance of end points $\approx 0.64\sigma_{beam-beam}$
- Four support structures
  - relative tolerance of mid points $\approx 0.5\sigma_{beam-beam}$

$\Rightarrow$ Only one support seems excluded

$\Rightarrow$ Chose two or four supports
  - four is conservative
  - two needs additional tolerance of motion on support



- For 2% luminosity loss the beam-beam jitter tolerance is 0.28 nm

  $\Rightarrow$ tolerance for quadrupole supports is 0.14–0.18 nm

  $\Rightarrow$ need stabilisation system

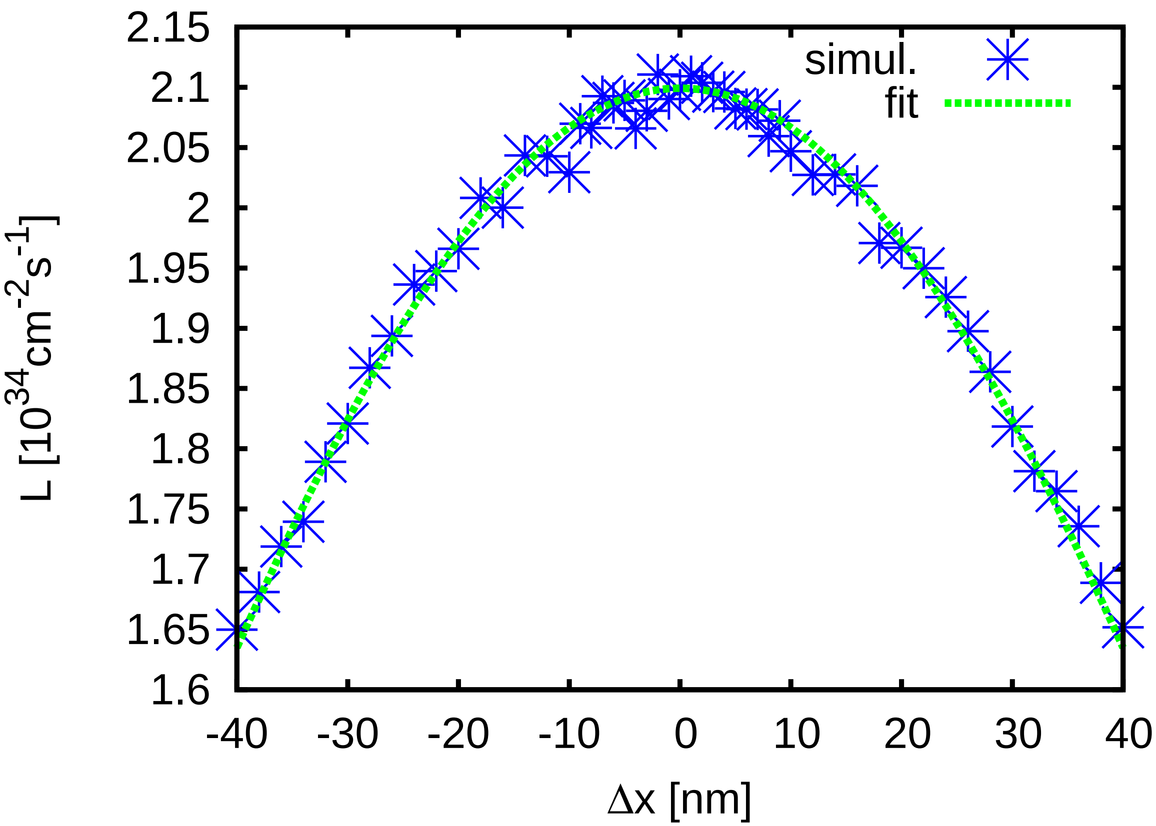
- Integration of support and stabilisation system in detector is important to study

Crab Cavity Phase Stability

- Required phase stability can be easily calculated
- What matters is relative phase of electron and positron crab cavity
- Horizontal offset at IP is

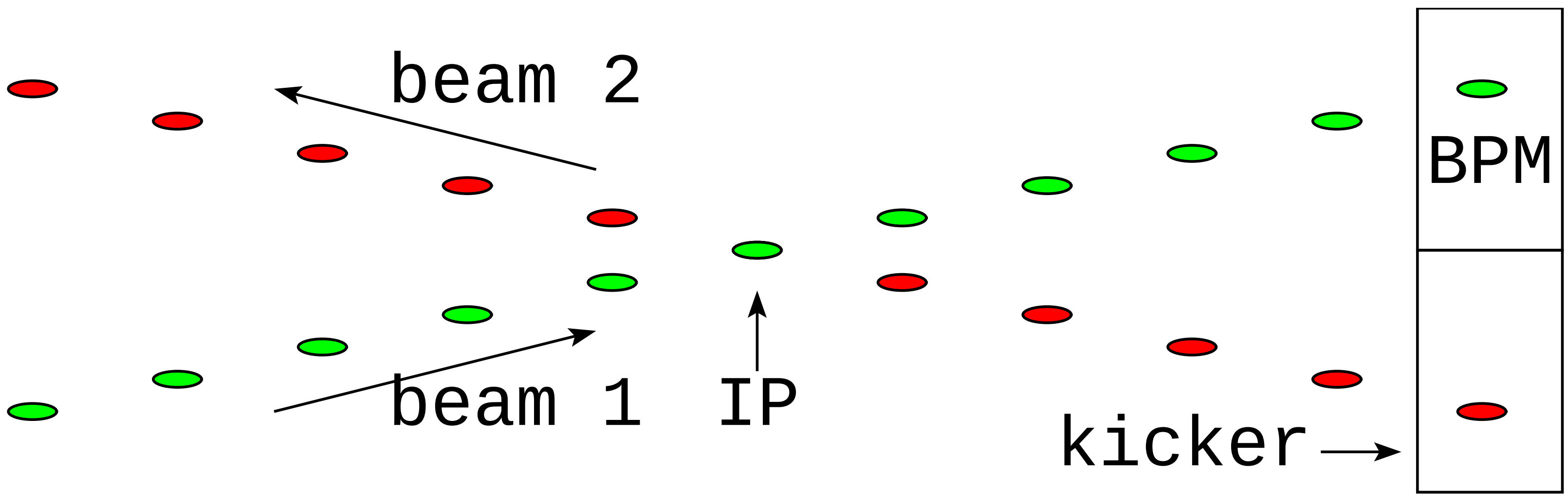
$$\Delta x = \frac{\theta_c}{2}\Delta\Phi$$

- For one 1% luminosity loss $\Delta\Phi \leq 0.011^\circ$



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 kicker and BPM in detector needs to be studied

Background Sources

- Machine produced background before IP

  beam tails from linac

  synchrotron radiation

  muons

  beam-gas, beam-black body radiation scattering

- Beam-beam background at IP

  beamstrahlung

  coherent pair creation

  incoherent pair creation

  hadron production

  secondary neutrons

- Spent beam background

  backscattering of particles

  especially neutrons

- Our strategy for these backgrounds is similar to ILC

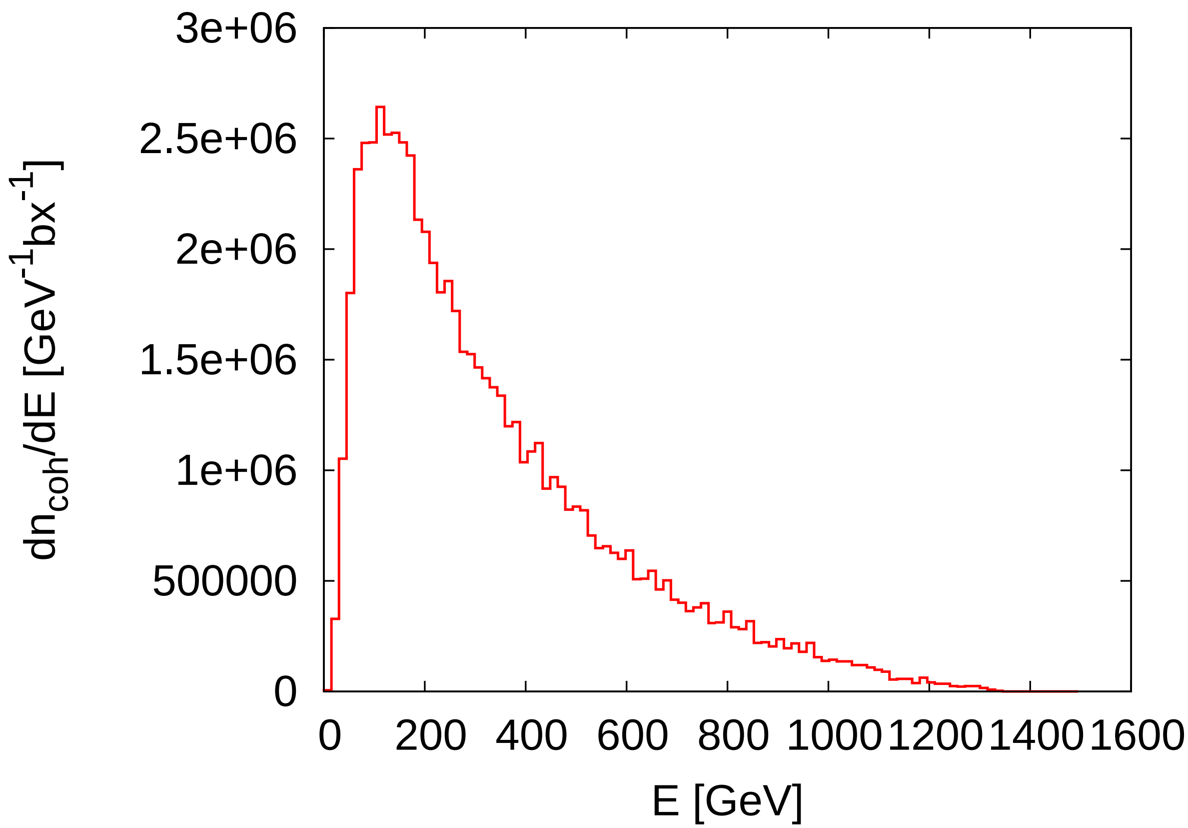
  - more detailed study needed

Coherent Pairs

- Coherent pairs are generated by a photon in a strong electro-magnetic field
- Cross section depends exponentially on the field

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

$\Rightarrow$ In CLIC, rate is substantial ($\approx 4 \times 10^8$ per bunch)



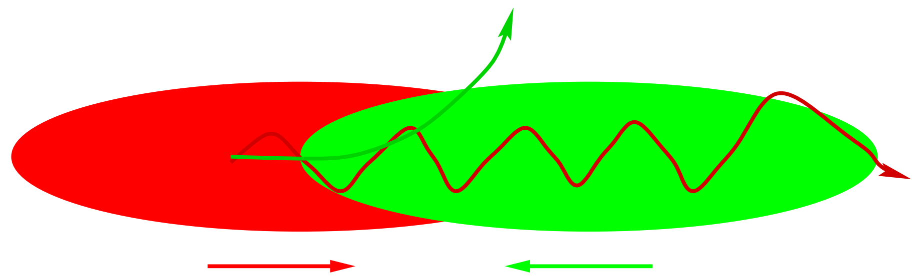
Need to foresee large enough exit hole (about 10mradian)

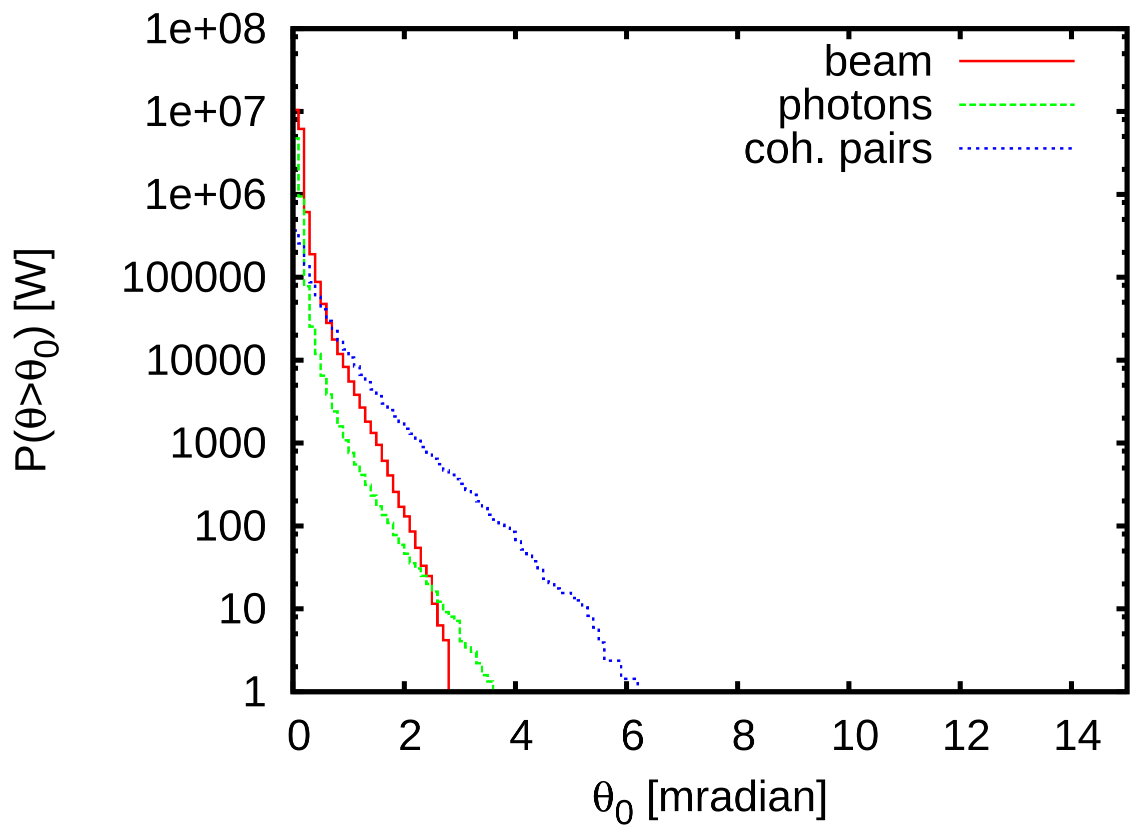
Spent Beam and Crossing Angle

- Lower limits on crossing angle from spent beam and multi-bunch kinck instability
- Crossing angle needs to be large enough to extract spent beam
- Exit hole for spent beam ¿10mradian
  - plus space for quadrupole (2cm in an old design)
- Kinck instability is OK
- Synchrotron radiation emission in solenoid seems OK

⇒ 20 mradian seems OK

- Somewhat smaller angles seem feasible
  - maybe 14 mradian





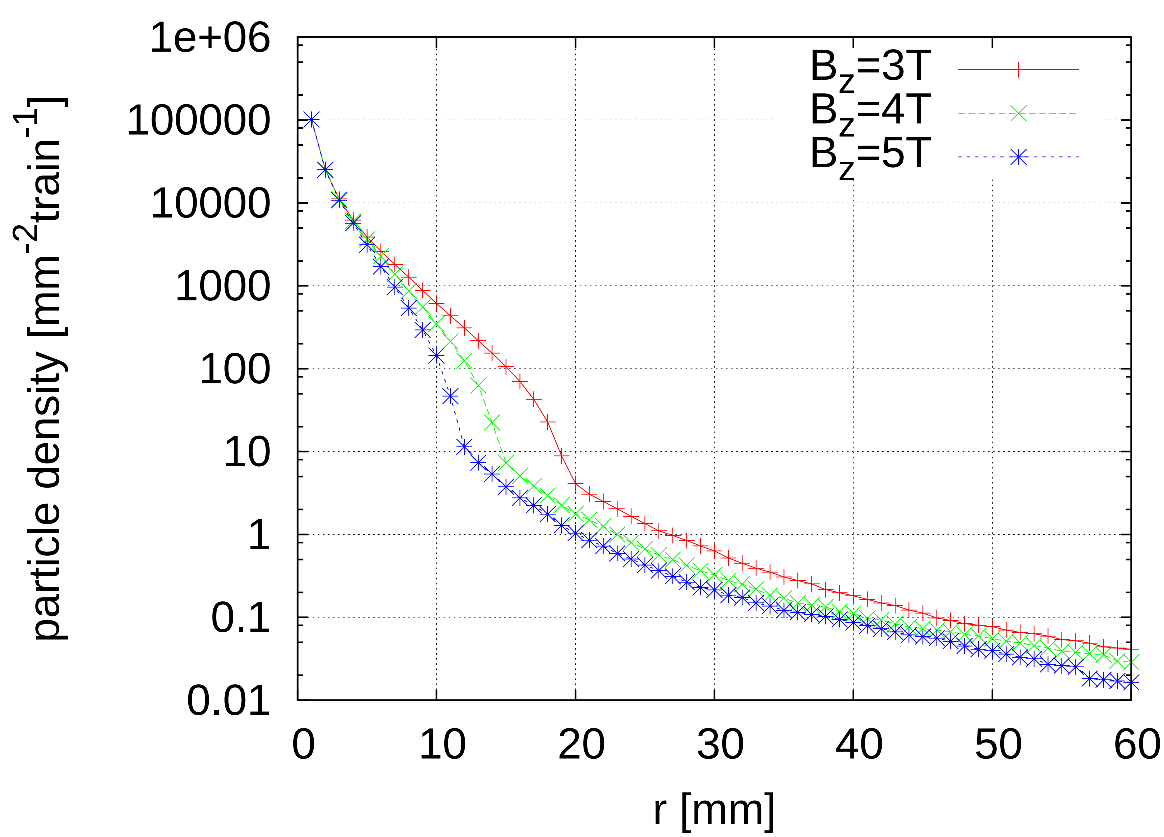
Impact of the Incoherent Pairs on the Vertex Detector

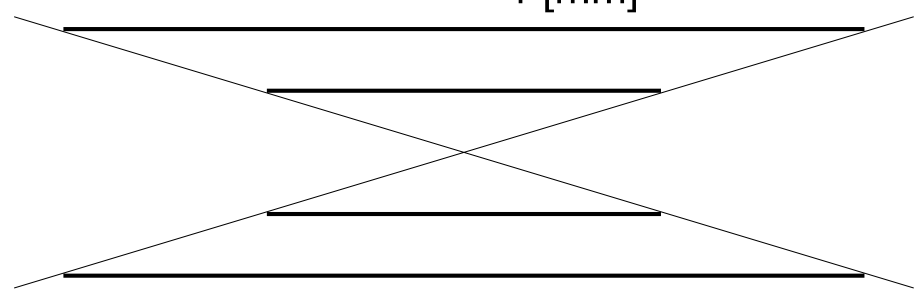
- Simplified study using simple cylinder without mass
  - coverage is down to $200\,\mathrm{mradian}$
- Simulating number of particles that hit at least once
  - experience indicates that number of hits is three per particle
  - but needs to be done with real detector parameters

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

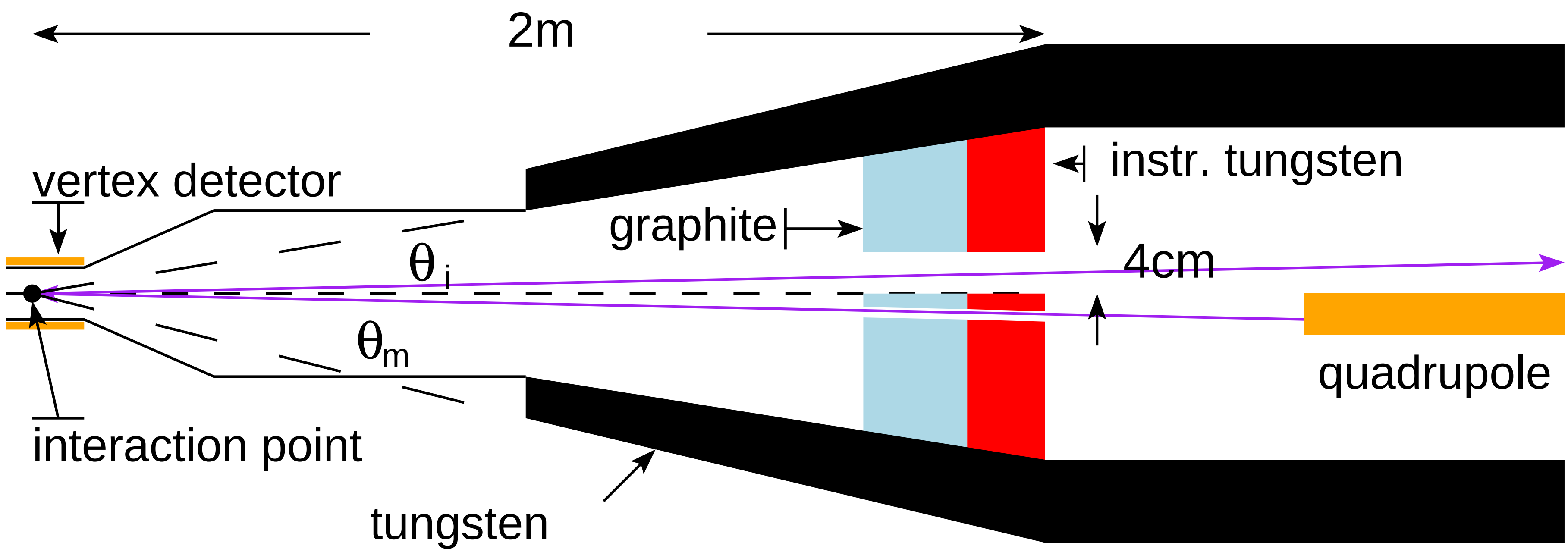
$\Rightarrow$ Detector should be a bit larger

  - but depends on technology





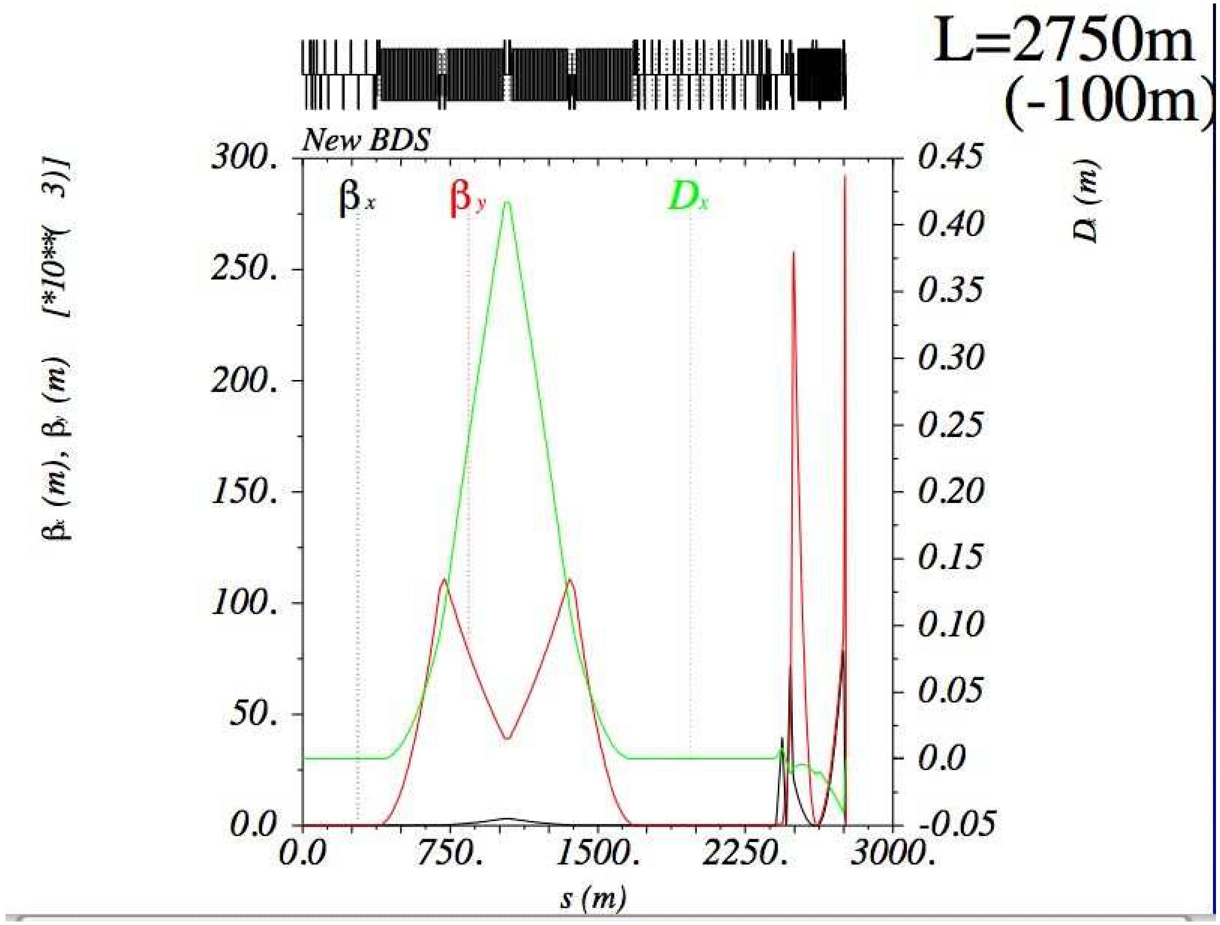
Mask Design



- Current CLIC design corresponds to old TESLA design
  - improvement is possible and needed
  - 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)

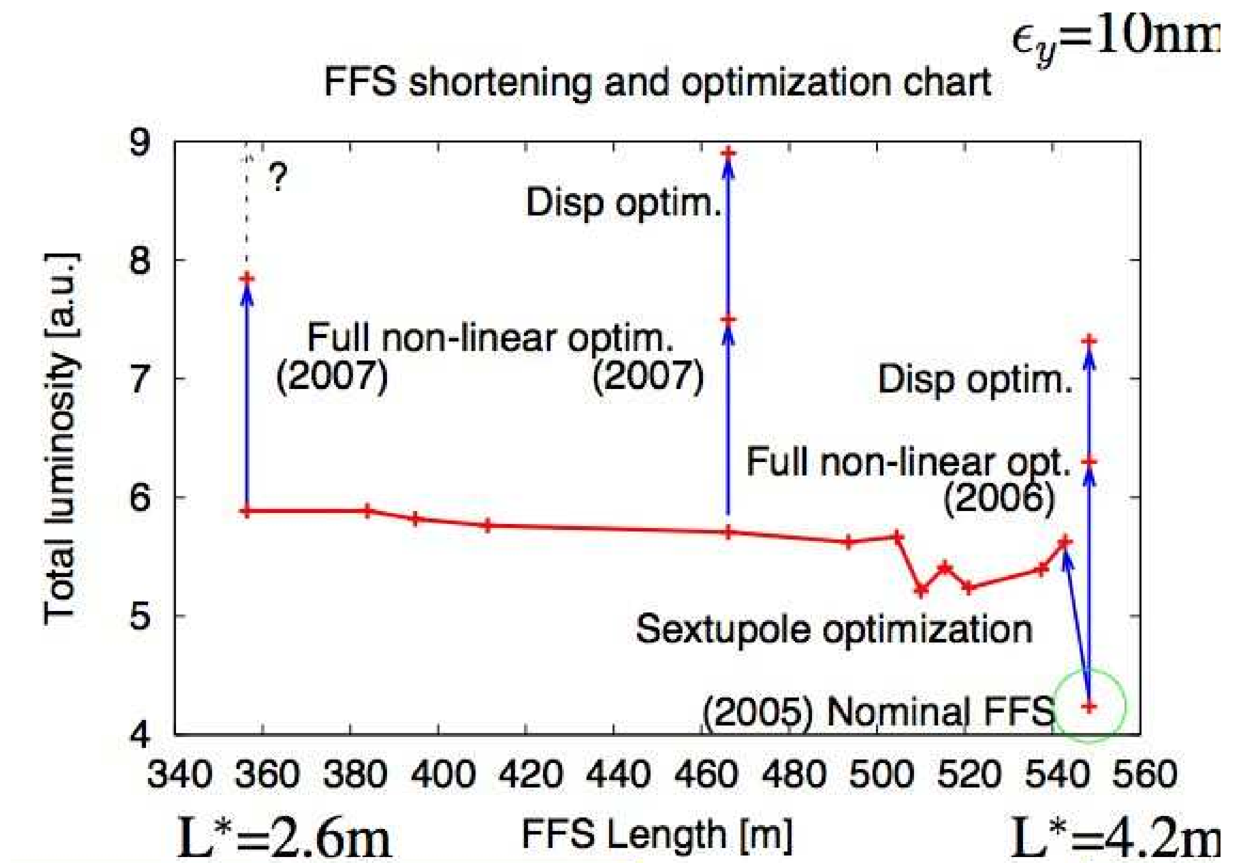
Beam Delivery System Design

- Design is based on scaled NLC lattice
  - has been strongly optimised by R. Tomas
- Further system optimisation is being used
- Beam-based alignment is being worked on
- First results for feedback indicate gain of 0.1 for ground motion B is OK



Final Focus System Optimisation

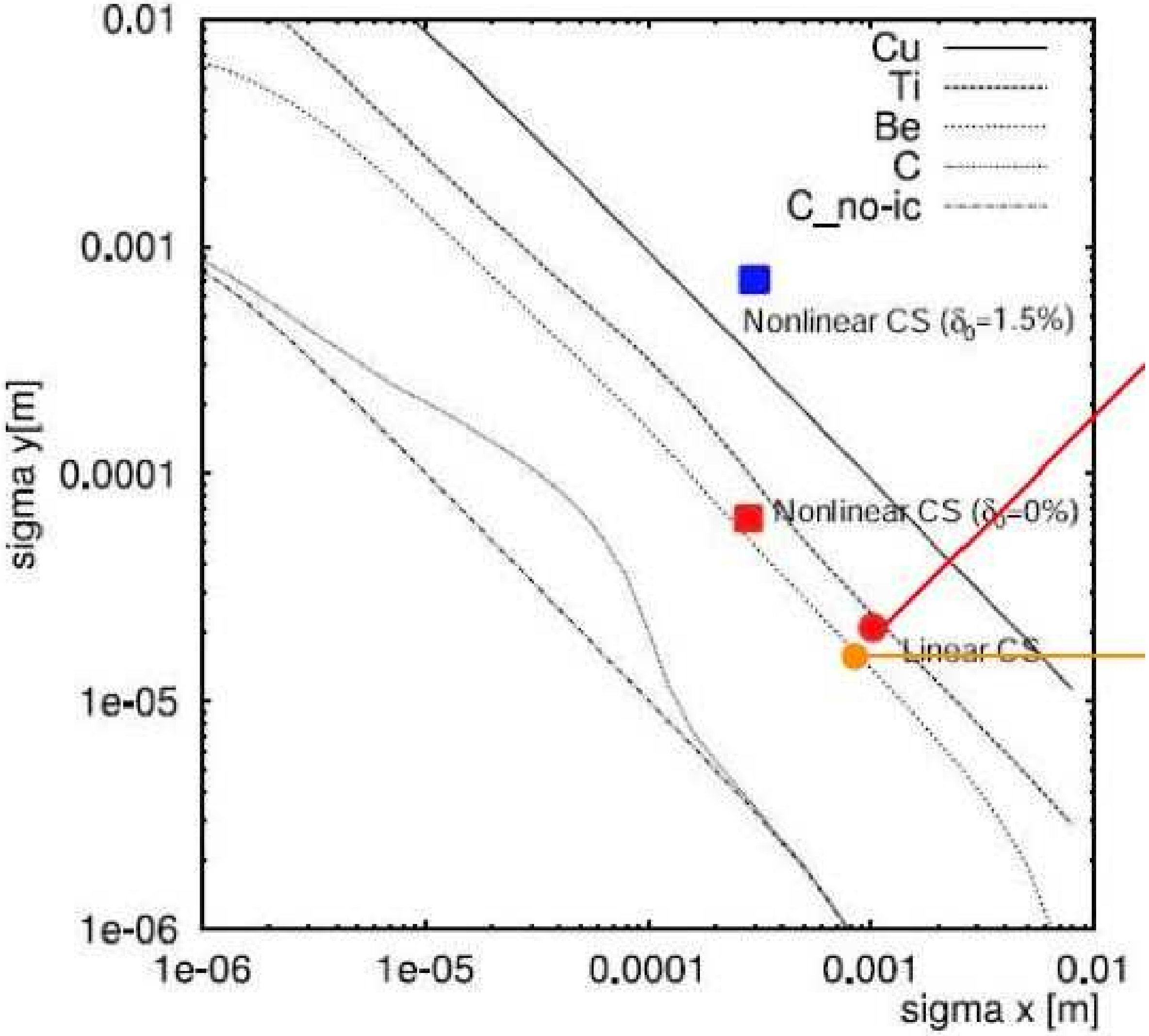
- Complex procedure
- It is not clear that we will continue to win a lot
- But beam size from beta-functions and initial emittances signififcantly smaller than actual beam size
  - we use a fit to Gaussian or beam-beam equivalent to determine σ_x and σ_y



Collimation System Design

- Two systems have been studied (J. Resta Lopez)
  - a linear one
  - a non-linear one
- Cleaning inefficiency can be quite good
- Higher luminosity with linear system
- Need to re-evaluate collimation system with new parameters
- More detailed study of performance with imperfections appears useful
  - collimator wakefields are strong

Collimator Survial



- Collimator survival is on the edge (Be)

  ⇒ need precise investigation of failure modes

- Potential remedies are

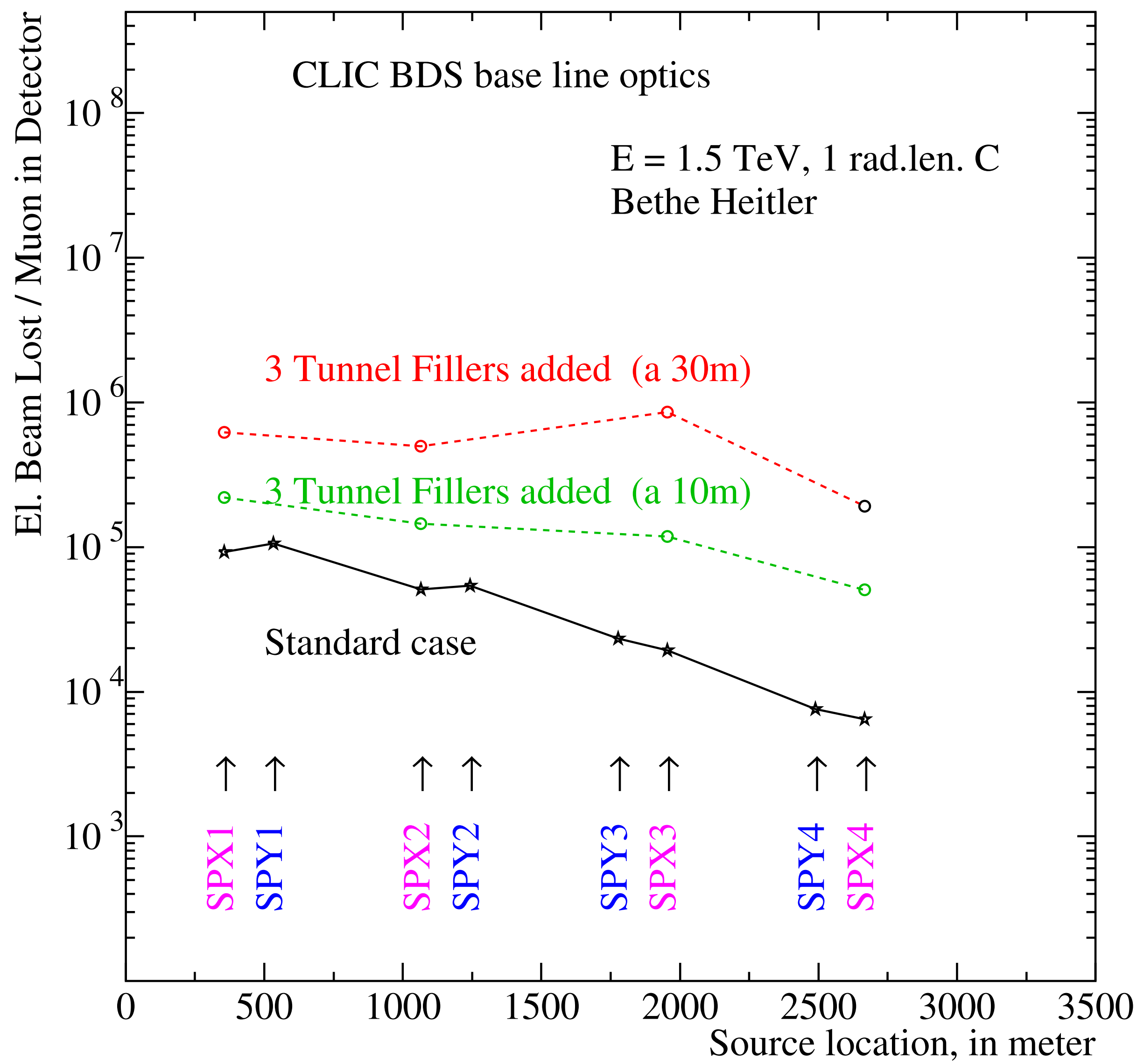
  - replaceable collimators
  - increase of beta-functions and system length

- non-linear collimation system (reduced luminosity)
- graphite collimators (but wakefields)

- Obviously LHC work is of interest

Muon Background

- Lost beam particles can generate secondary muons
  - Bethe-Heitler process (simulated)
  - production by photons in the shower
  - by hadronic processes
- Simulations performed with BDSIM (H. Burkhardt)
  - total muon rate expected to be twice larger
- Muons are hard to stop
- Potential means is use of tunnel fillers of magnetised iron
  - problems with tunnel access
  - high cost



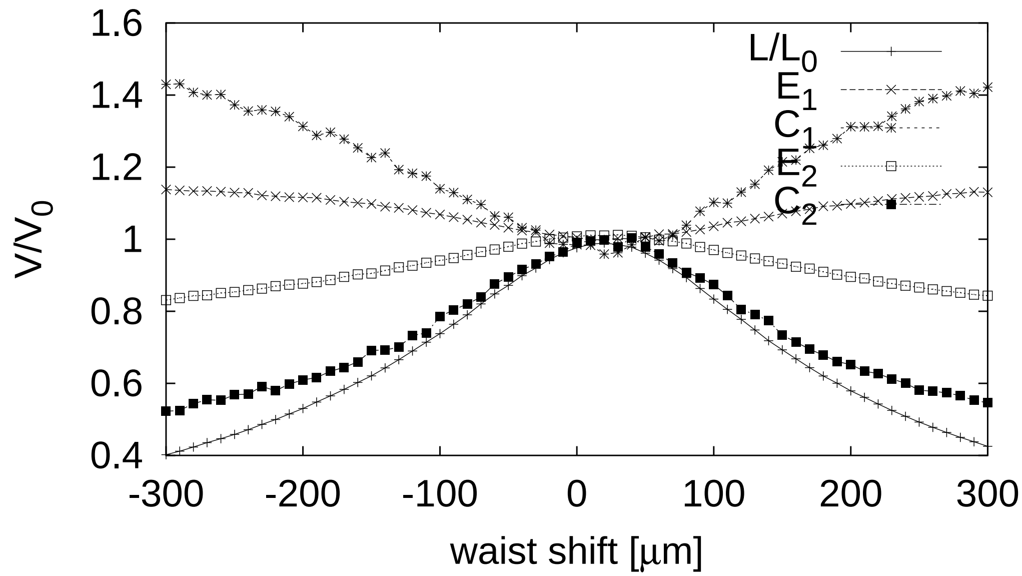
Muon Rate

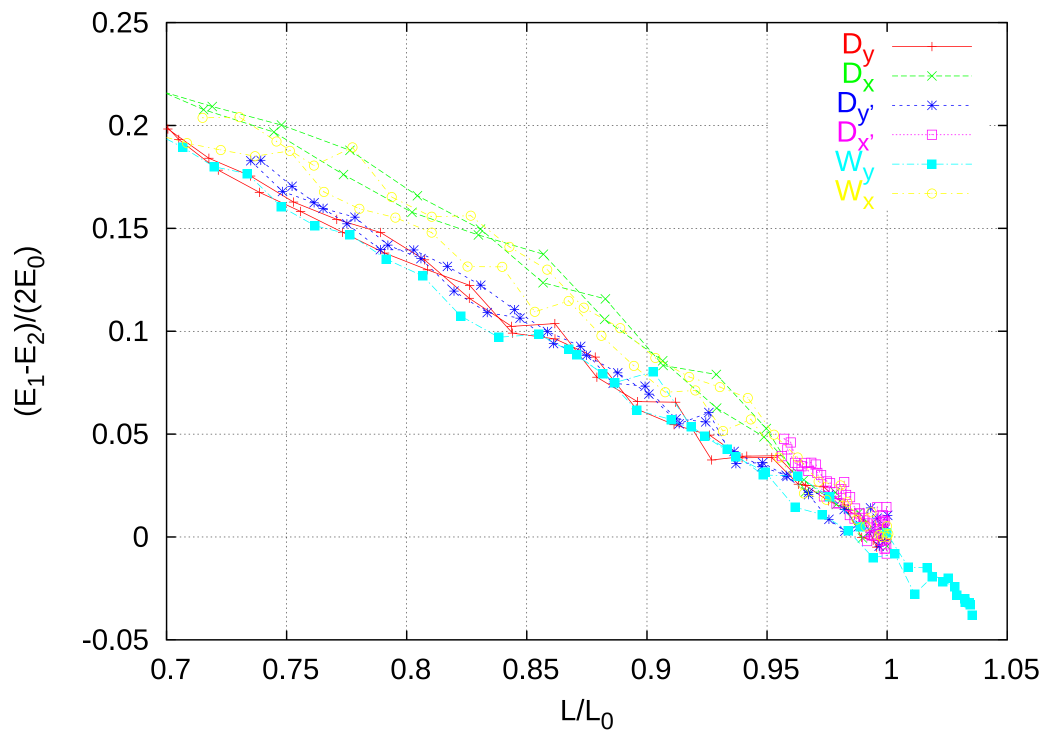
- Rate depends critically on assumption about beam halo
  - expect small values (some 10^{-4} for a vacuum pressure of $10\,\mathrm{ntorr}$, H. Burkhardt, needs more studies)
  - SLC experience has been bad (up to 0.01)
- For a beam halo of 10^{-3} we expect 5×10^4 muons per train in the detector
- Tunnel fillers can reduce this by an order of magnitude
- Better vacuum will help
  - beam stability requires very good vacuum
- But the detector will need to be able to cope with many muons
- Would follow ILC strategy
  - foresee place for tunnel fillers
  - but install them only if necessary

Post Collision Line Requirements

- Transport of beam with reasonable losses
  - no distruction of beam line elements
  - limited background
- Instrumentation is needed
  - No direct fast luminosity signal is available
  - Need such a signal for beam tuning

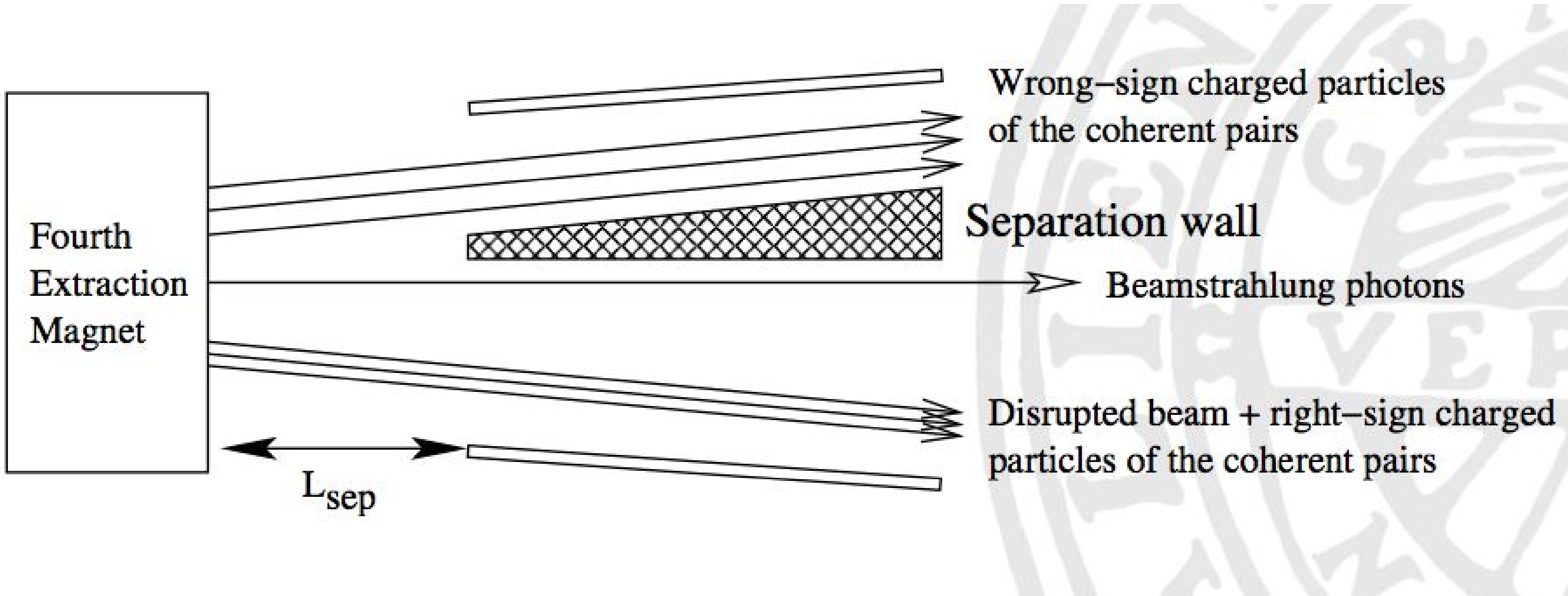
  ⇒ Use signals to tune knobs (P. Eliasson, D.S.)
  - Good candidate is beamstrahlung





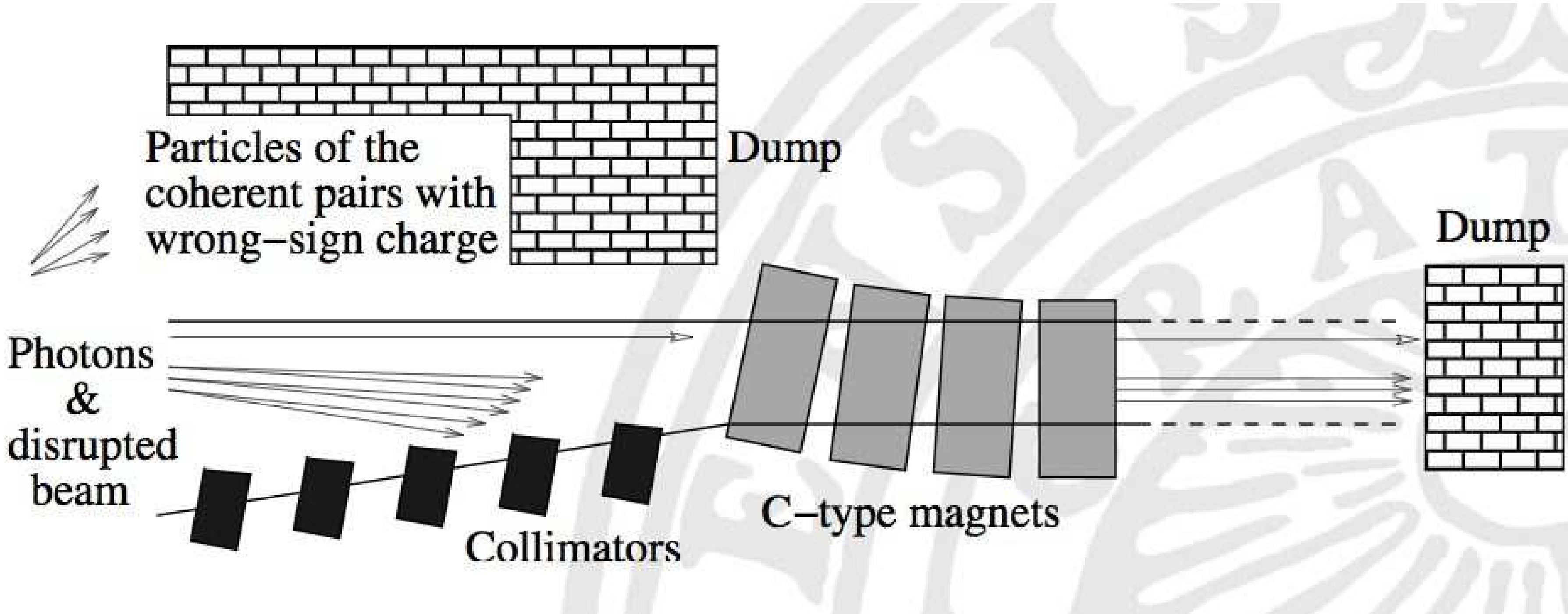
Post Collision Line Conceptual Design

- Post collision line is very challenging since beam energy spectrum goes down to almost zero energy
- Coherent pairs even lead to large flux of wrong sign of charge particles



- Design by A. Ferrari (Uppsala)
- Basic idea is to seperate wrong sign of charge coherent pairs, beamstrahlung and beam

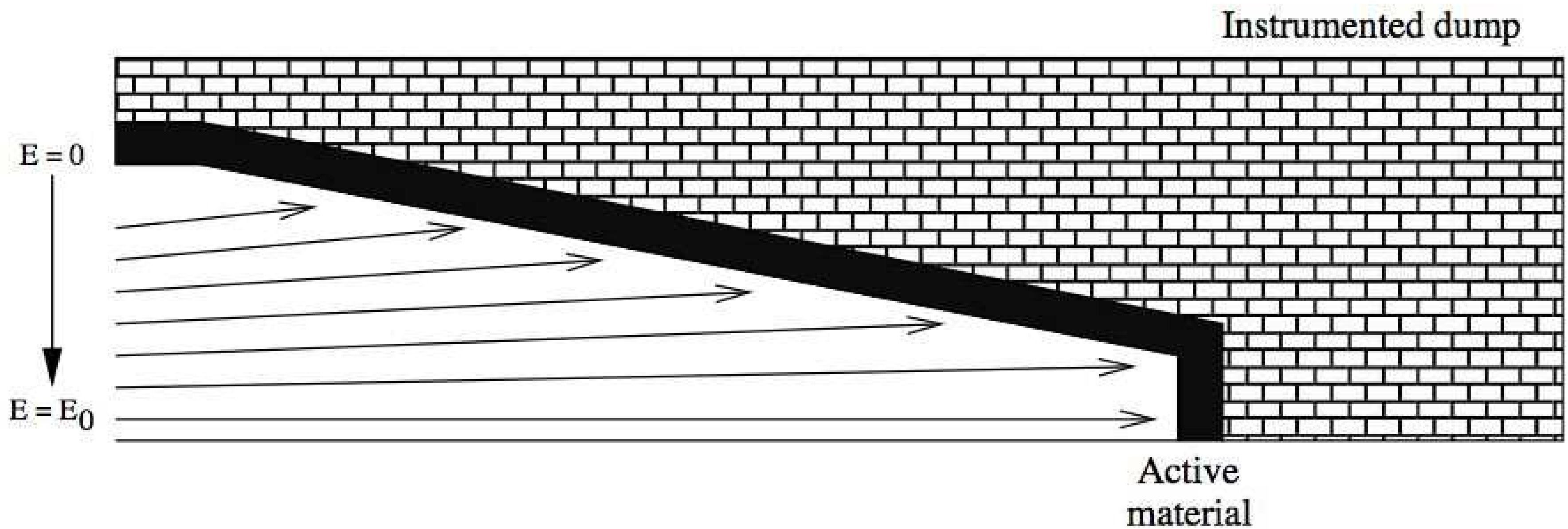
Post Collision Line Conceptual Design 2



- Undisrupted beam size must be large at extraction window
  - litte impact of optices

  $\Rightarrow$ large distance to IP
  - C-type magnets to have $D'_y = 0$ at dump
  - huge quadrupoles with $\approx 2 \times 0.7\,\mathrm{m}$ aperture

Post Collision Line and Extraction Window



- An instrumentated dump could even seperate coherent pairs according to energy
- but not all pair particles make it to the dump
  - lower energy particles are lost before

Beam Dump

- Distance to IP is $\approx 250\,\mathrm{m}$
- Beam power is 14 MW
- Window is critical
  - suggested is carbon-carbon composite (SIGRABOND 1501G) with metal foil to make it leak tight
  - $15\,\mathrm{mm}$ carbon, $0.2\,\mathrm{mm}$ foil

Material	ρ (g/cm^3)	C (J/g K)	k (W/K cm)	ΔT_{inst} (K)	ΔT_{eq} (K)
C-C	1.50	0.53	0.24	1.1	103.5
Steel 316	7.80	0.50	0.16	1.0	639.8
Aluminium	2.70	0.90	2.37	0.6	17.4
Titanium	4.54	0.53	0.22	1.0	314.2
Copper	8.96	0.38	3.90	1.3	32.8

Tools we Use

- Simulations
  - GUINEA-PIG: can generate luminosity spectra, electromagnetic and hadronic background, polarization to be included
  - HTGEN: development of modules to simulate generation of beam halo and tails
  - BDSIM: to track beam halo and tails (GEANT based)
  - PLACET: to simulate realistic beam conditions
- Data bases (need to be updated for latest parameters)
  - CALYPSO: Beam particle collisions with full correlation
  - HADES: Hadronic background events, uses PYTHIA for generation (maybe something to improve)
  - files with pairs

Conclusions

- CLIC interaction region studies need to be strengthened
- Rising interest at CERN
  - profit from LHC expertise
  - resources will appear slowly
- Would welcome contributions
  - can learn from LHC
  - can learn from ILC
  - and from others (e.g. crab cavity from KEK)