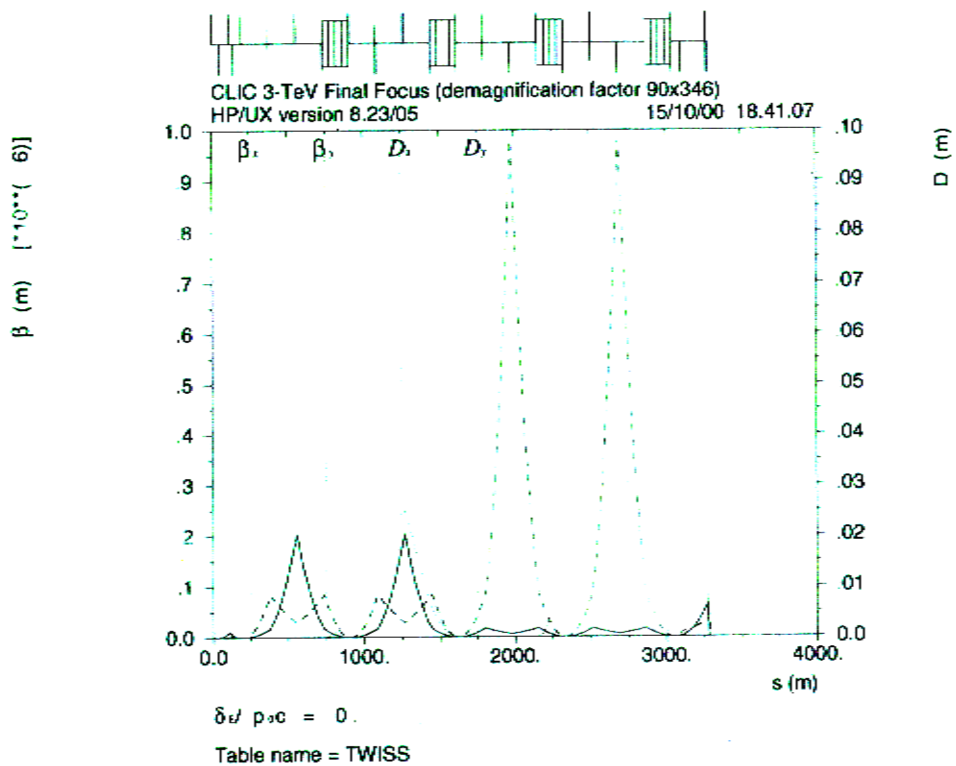
Basic Parameters

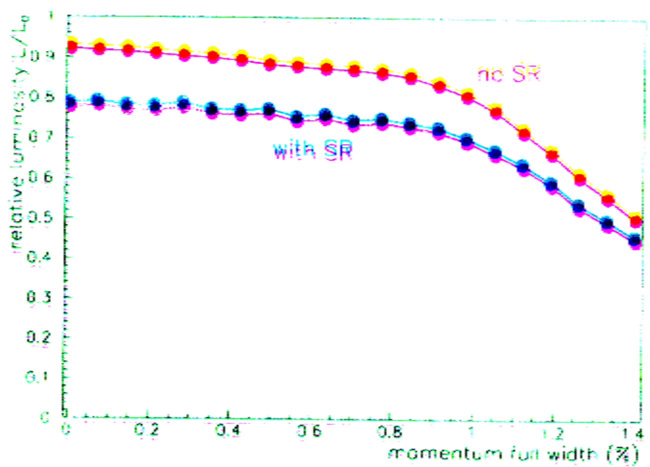
E_{cm}	[TeV]	0.5	1.0	3.0	5.0
$\mathcal{L}$	$[10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}]$	1.4	2.7	10.0	10.0
f_{RF}	[GHz]	30	30	30	30
G_{load}	[MV/m]	150	150	150	172
η	[%]	9.8	9.8	9.8	8.5
f_r	[Hz]	200	150	100	50
N_b		154	154	154	154
Δ_b	[ns]	0.67	0.67	0.67	0.67
N	$[10^{10}]$	0.4	0.4	0.4	0.4
σ_z	[μm]	30	30	30	30
ϵ_x	[μm]	2.0	1.3	0.68	0.78
ϵ_y	[μm]	0.02	0.02	0.02	0.02
σ_x^*	[nm]	202	115	43	31
σ_y^*	[nm]	2.5	1.75	1	0.78
δ	[%]	4.4	11.2	31	36.6
n_γ		0.7	1.1	2.3	3.2
N_{pairs}	$[10^3]$	21	66	455	874
E_{pairs}	$[10^6$ GeV$]$	0.11	1.2	38.5	126.5
N_{coh}	part.	700	$3 \cdot 10^6$	$6.7 \cdot 10^8$	$1.8 \cdot 10^9$
E_{coh}	$[10^9$ GeV$]$	10^{-4}	0.8	440	1630
$N_\perp$		4.4	11.1	60	112
N_H		0.047	0.28	4.05	9.6

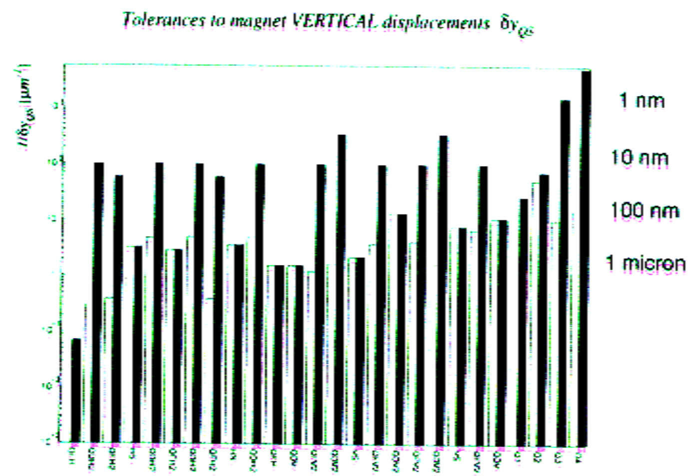
3-TeV Final Focus



characteristics:

total length 3.282 km, demagnification factors 90 (x) and 346 (y), peak beta function 1000 km, odd dispersion à la Oide (JLC design), trade-off Oide effect & higher-order chromaticity, ~1% energy bandwidth, 80% of ideal luminosity. The four bending sections are each 176 m long, bending angles are 63 μrad (CCX) and 230 μrad (CCY).





Left: relative luminosity vs. full energy spread of a flat distribution; ideal luminosity w/o pinch: $L_0 = 4.6 \times 10^{34}$ cm^{-2}s^{-1}.

Right: vertical displacement tolerances corresponding to 2% luminosity loss. The tightest jitter tolerances (black bars) are about 0.2 nm (3 nm horizontally); drift tolerances (white bars) are of the order of 20–100 nm.

Energy Spread

There are four main sources of energy spread at the IP

initial state radiation

$\Rightarrow$ unavoidable

$\Rightarrow$ has sharp peak

beamstrahlung

$\Rightarrow$ similar shape as ISR

$\Rightarrow$ can be reduced by reducing luminosity

single bunch energy spread

due to single-bunch beam loading and RF curvature

$\Rightarrow$ part cannot be avoided

$\Rightarrow$ helps in stabilising the linac

$\Rightarrow$ $\mathcal{O}(1\,\%)$ (better for TESLA)

$\Rightarrow$ now included in simulation

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

$\Rightarrow$ $\mathcal{O}(0.1\,\%)$

CALYPSO

Allows to include luminosity spectrum in event generators

returns

- e^+e^-, e^-e^-, e^+e^+ and e^-e^+ collisions
- $e\gamma$, ...
- $\gamma\gamma$

included effects are

- beam energy spread
- beamstrahlung

all correlation effects are kept (GUINEA-PIG)

longitudinal position of collision is returned

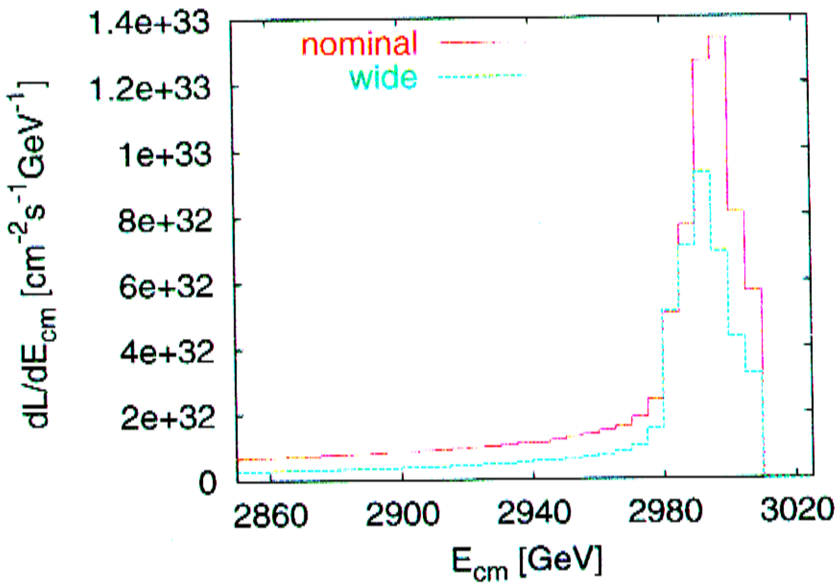
uses large files

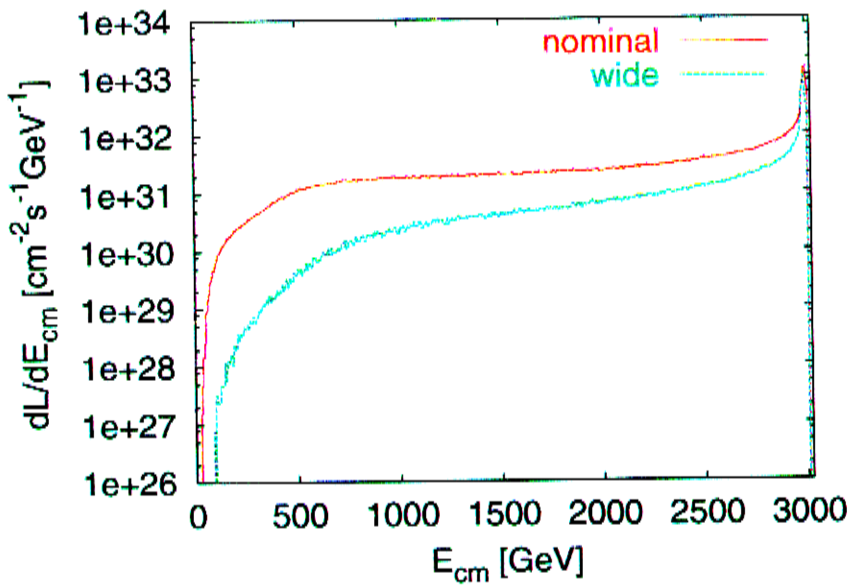
will also use (approximate) parametrisation soon

and density function $\mathcal{L}(E_1, E_2)$

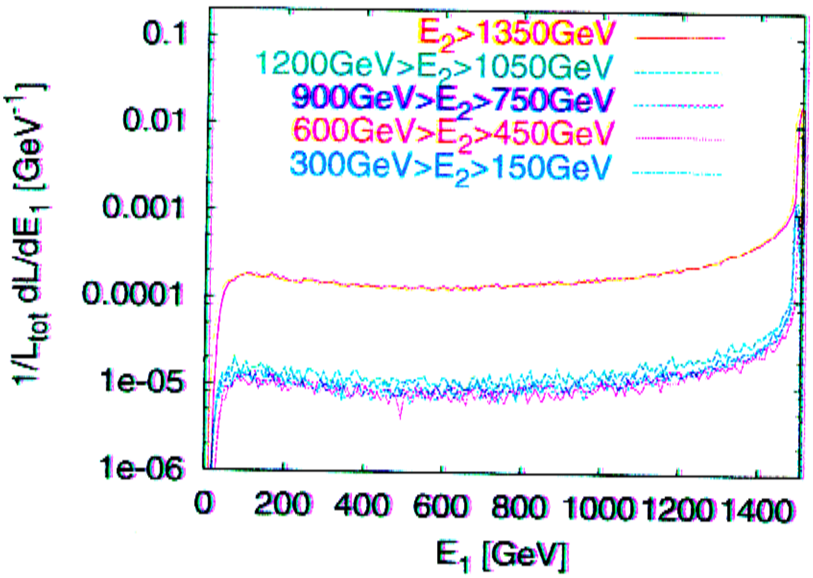
included in CLIC version of SIMDET

Spectra in CLIC at $E_{cm} = 3\,\mathrm{TeV}$





Correlation of the Spectra

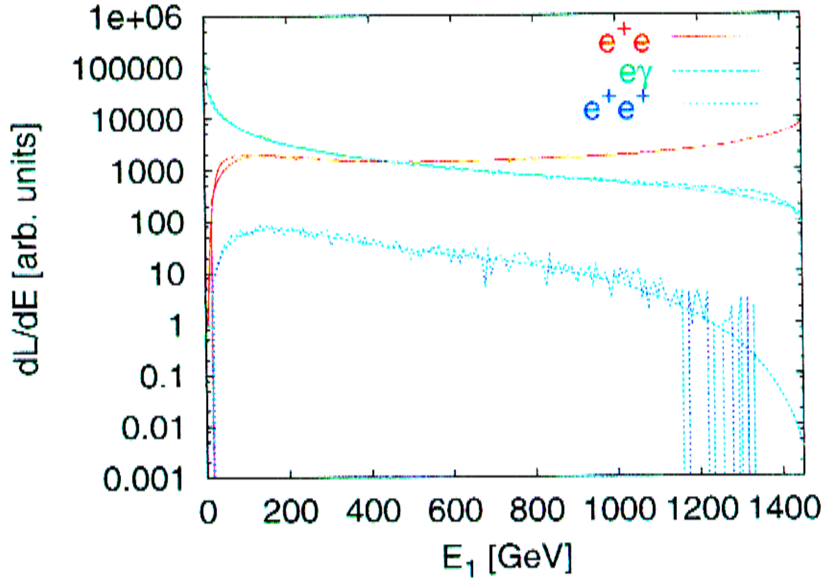


Consider tail only

plot spectra of beam 1 for different energies ranges for particle from beam 2

$\Rightarrow$ correlation seems to be small

Parametrisation of the Spectra



Use functions of the form

$$f(x) = Ax^{\alpha}(1-x)^{\beta}$$

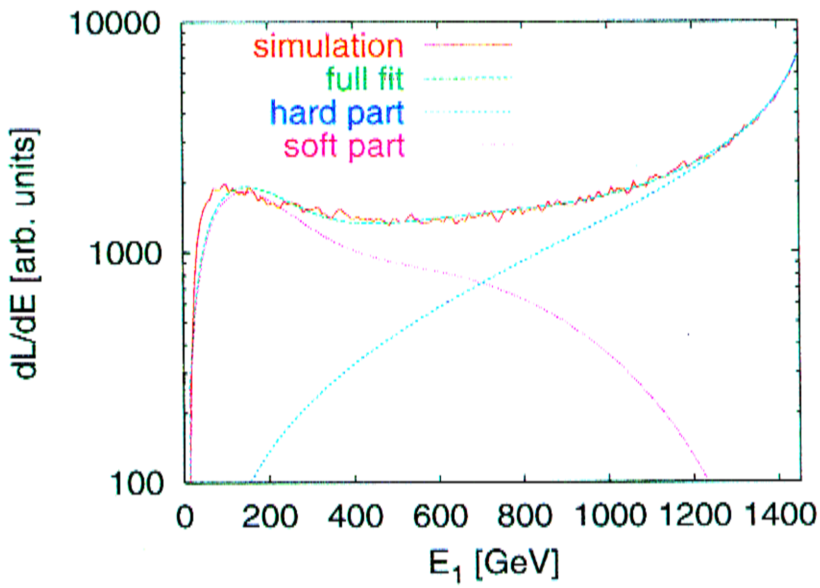
(same as in CIRCE)

two for photons

two for coherent pairs

four for beam (including two for coherent pairs)

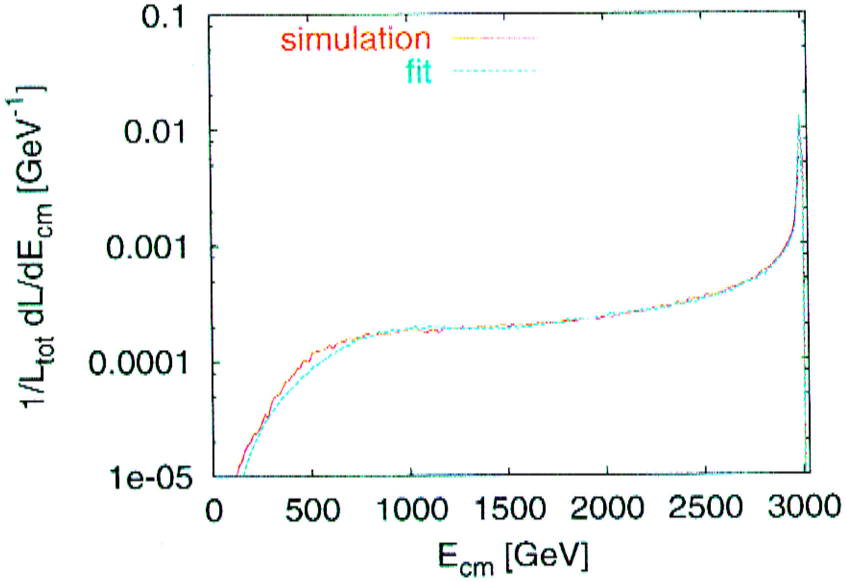
Parametrisation of the Tail



⇒ Parametrisation seems good

⇒ but have to see for soft part

Preliminary Parametrisation



Consider four cases

$$E_1 > \check{E}_0,\ E_2 > \check{E}_0$$

$$E_1 > \check{E}_0,\ E_2 < \check{E}_0$$

$$E_1 < \check{E}_0,\ E_2 > \check{E}_0$$

$$E_1 < \check{E}_0,\ E_2 < \check{E}_0$$

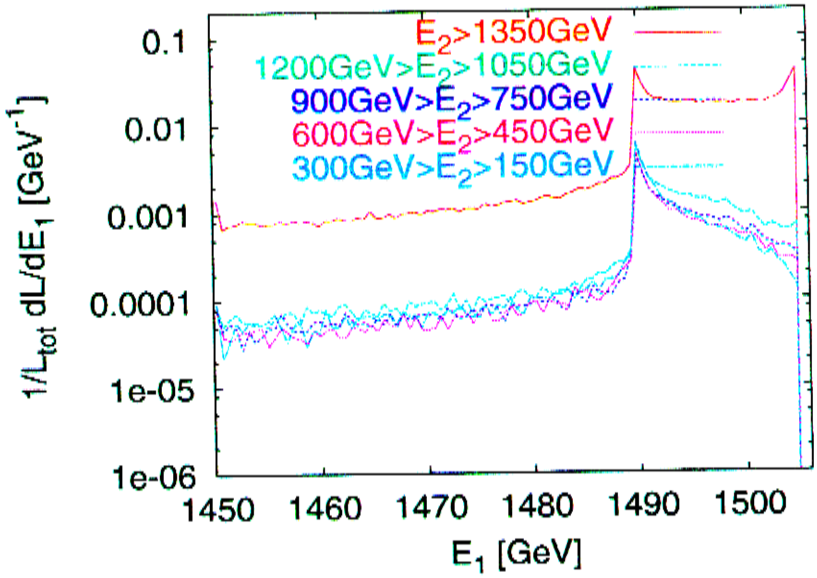
replace $E_i < \check{E}_0$ with $f(E_1/E_0)$

replace $E_i > \check{E}_0$ with constant (to be improved)

use proper weights for the four cases

$\Rightarrow$ approximation seems good for the tail

Luminosity in the Peak



Strong correlation visible

> may not be too important because effective only if one particle lost a significant amount of energy
>
> but may be important in measuring the spectrum

more work to be done

Particular Problems of CLIC

At low energies CLIC is comparable to NLC/JLC

luminosity is delivered in ≈ 100 $100\,\mathrm{ns}$ bursts per second

distance between bunches is $0.67\,\mathrm{ns}$

$\Rightarrow$ detector design should be different from TESLA

$\Rightarrow$ need crossing angle (multibunch kink instability)

$\Rightarrow$ need good time resolution

$\Rightarrow$ need high granularity

CLIC at high energies

more luminosity

higher energy

higher relative energy loss

$\Rightarrow$ more background

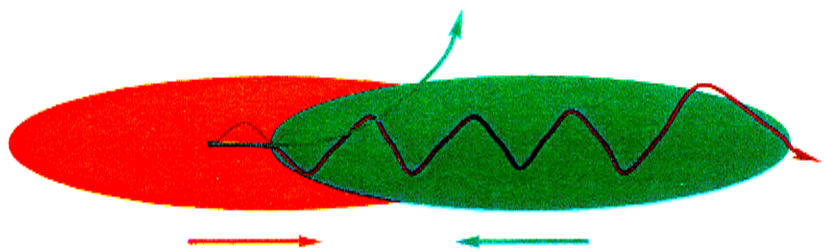
high upsilon-parameter

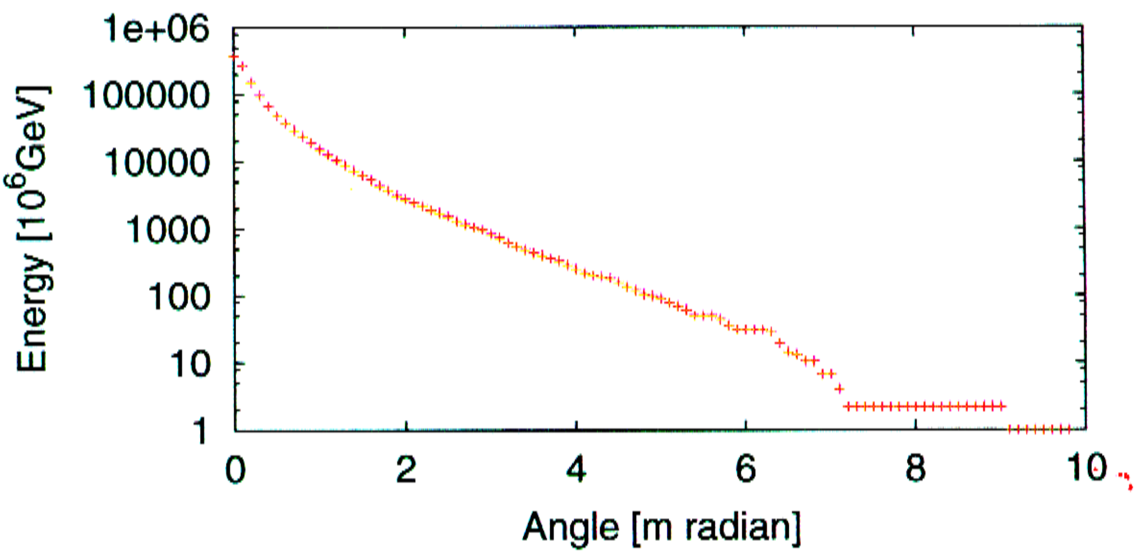
$\Rightarrow$ new background source

Coherent Pairs

E_{CM} [TeV]	no of pairs	$E_{coh}[10^9\,\mathrm{GeV}]$
0.5	700	10^{-4}
1	$3 \cdot 10^6$	0.8
3	$6.7 \cdot 10^8$	440
5	$1.8 \cdot 10^9$	1630

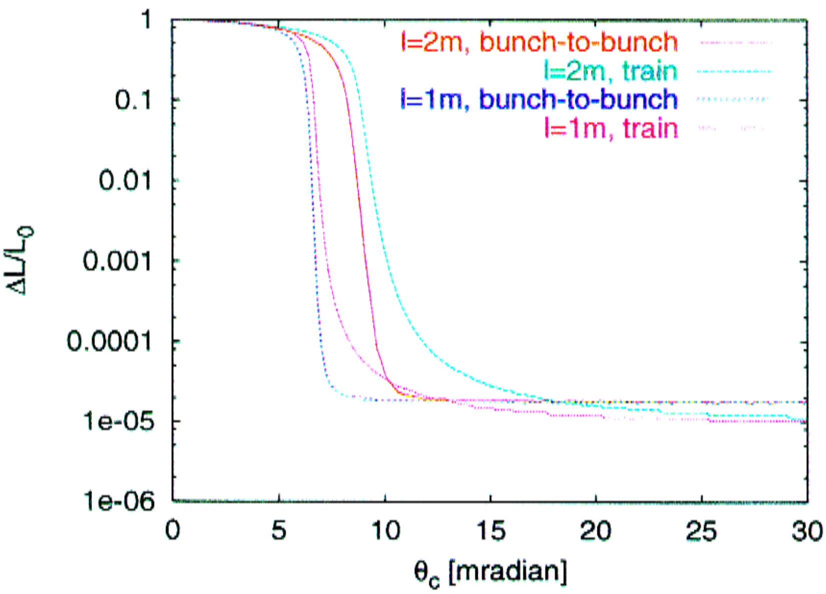
$\Rightarrow$ significant fraction of bunch charge $(4 \cdot 10^9)$





$\Rightarrow$ exit angle larger than $10\,\mathrm{mradian}$

Multi-Bunch Kink Instability



Two main contributions to kick

beam

coherent pairs

kick is approximated

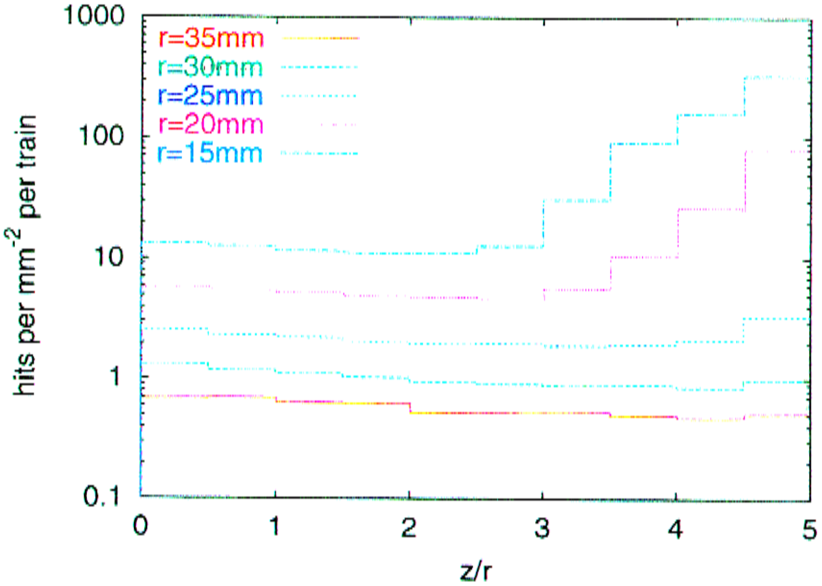
bunches are separated after $l = 2\,\mathrm{m}$ $(1\,\mathrm{m})$

$\Rightarrow$ at $\theta_c = 20\,\mathrm{mradian}$ luminosity loss is increased by $\approx 60\,\%$ for coherent offset

$\Rightarrow$ only $\approx 13\,\%$ for $l = 1\,\mathrm{m}$

$\Rightarrow$ more precise model needed

Vertex Detector Simulation



r	[mm]	15	20	25	30	35
ρ	$[\mathrm{mm}^{-2}\mathrm{BT}^{-1}]$	69	15	2.2	1.0	0.57

GEANT simulation of inner vertex detector layer

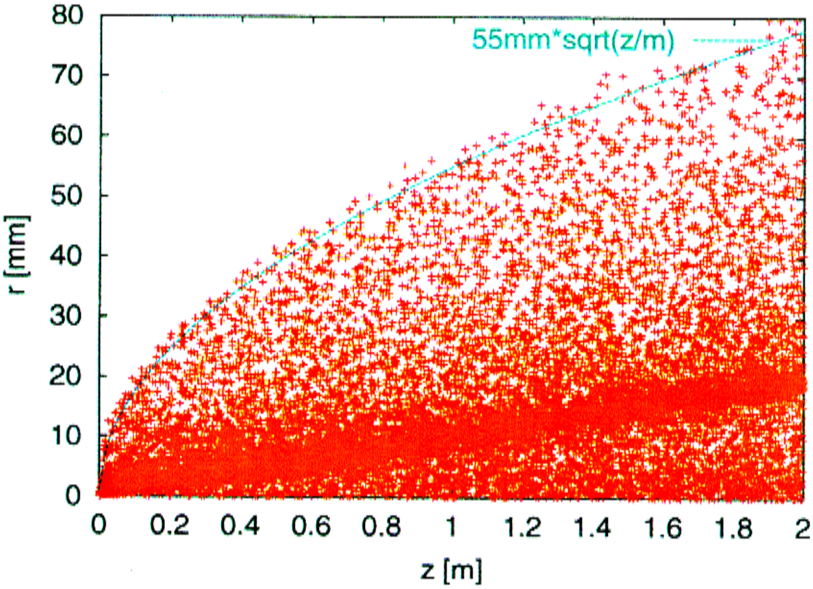
no backscattering taken into account

should be suprresed by mask

one to a few hits per mm^{-2} are acceptable

$\Rightarrow r \geq 30\,\mathrm{mm}$

Mask Angle



Assumed crossing angle $\theta_c = 20\,\mathrm{mrad}$, $B_z = 4\,\mathrm{T}$, $l^* = 2\,\mathrm{m}$

$\Rightarrow$ lowest tag angle: $\theta_0 \approx 40\,\mathrm{mradian}$

distance IP to mask opening

longer distance $\longrightarrow$ more background

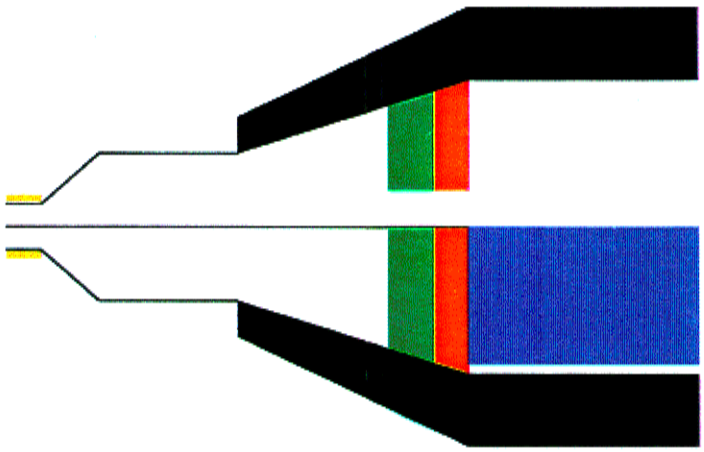
shorter distance $\longrightarrow$ smaller mask angle

$\Rightarrow$ take $z_0 = 1\,\mathrm{m}$ $\longrightarrow$ inner radius $a = 80\,\mathrm{mm}$

thickness of mask $80\,\mathrm{mm}$ at cylindrical part (from TESLA experience , verfied by simulation)

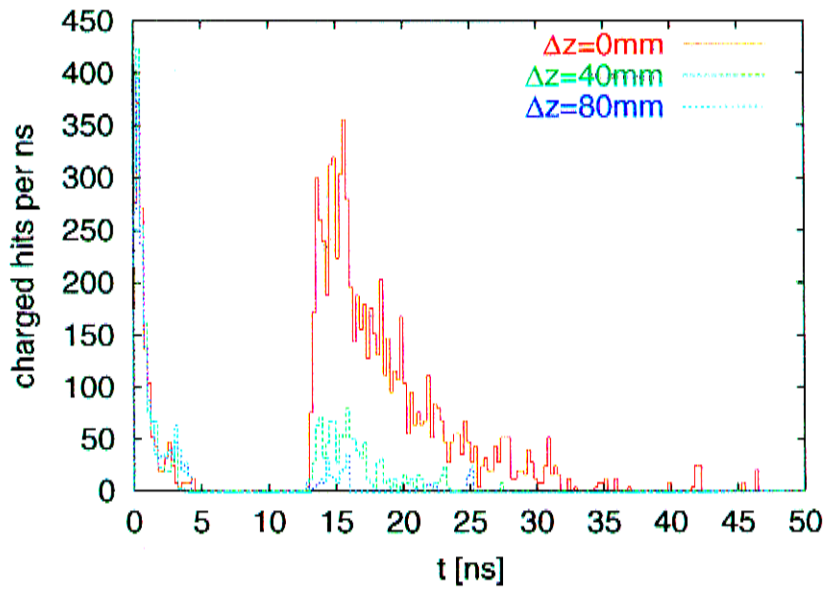
$\Rightarrow$ mask outer angle: $\theta_{mask} \approx 120\,\mathrm{mradian}$

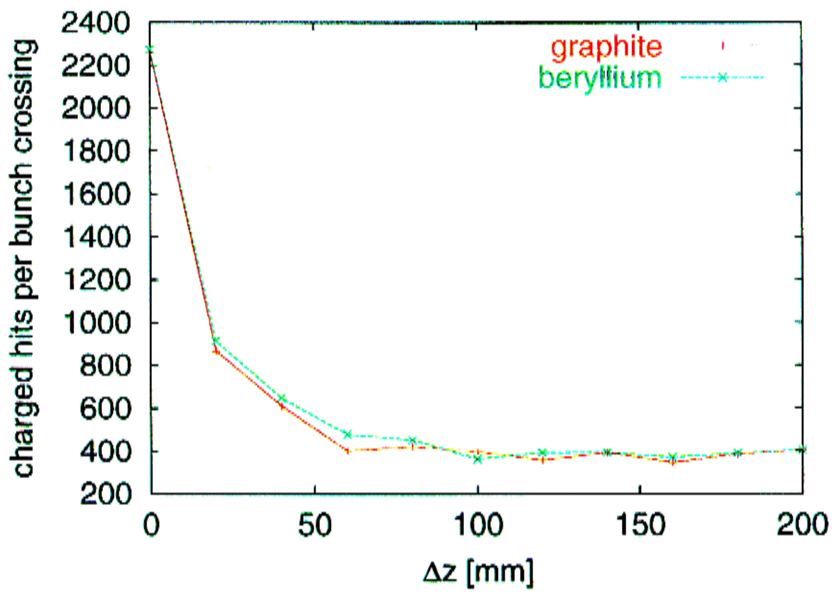
Mask Design



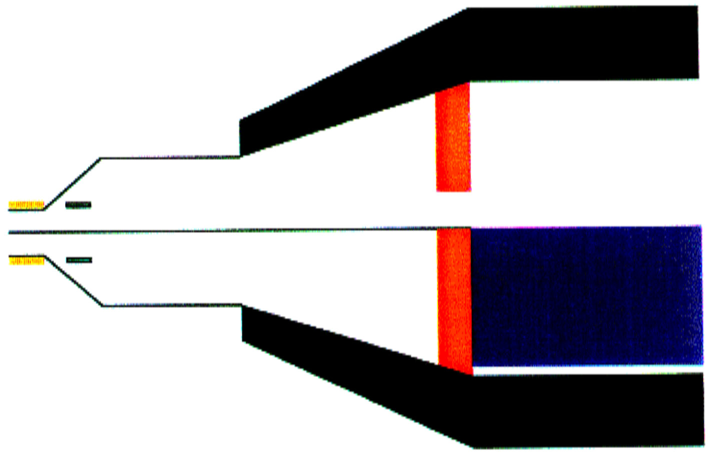
- no final design
- preliminary design to have first idea of background
- outer mask to prevent backscattering of photons
- inner mask to prevent backscattering of charged particles
- inner mask should instrumented for the machine
- instrumentation for low angle tagging will be included later

Backscattering of Pairs





Tube Mask



can protect all of the vertex detector

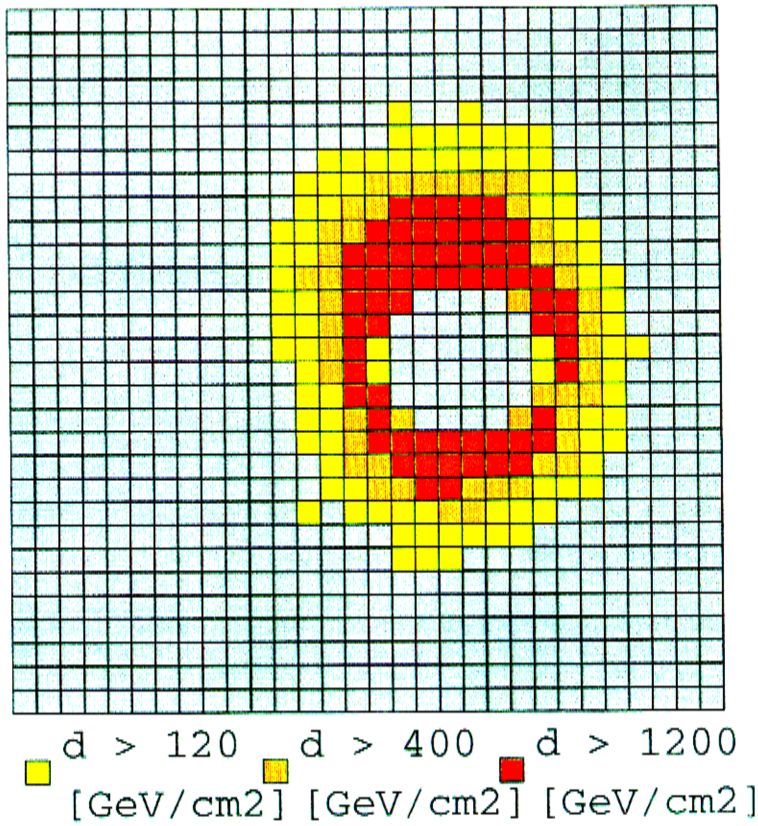
problems

- close to VTX $\longrightarrow$ more photons in central tracker (about factor 5)
- far from VTX $\longrightarrow$ less certain about field lines

$10\,\mathrm{cm}$ $(20\,\mathrm{cm})$ long beryllium mask does help a little

but still ≈ 800 hits

Energy in the Inner Mask



total energy from incoherent pairs (shown above)

$\approx 50\,\mathrm{TeV}$ per side and bunch crossing

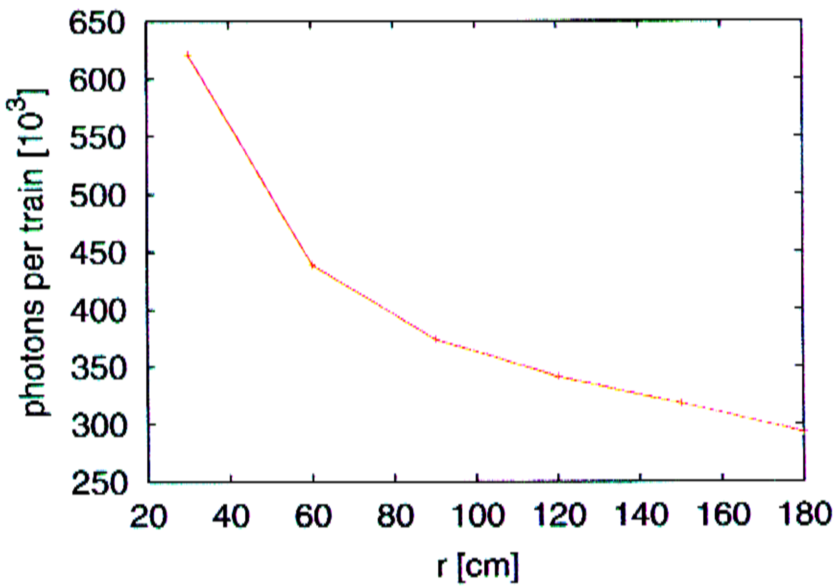
total energy from coherent pairs

$\approx 200\,\mathrm{TeV}$ per side and bunch crossing

but extremely small statistics

$\Rightarrow$ has to be verified

Central Tracker



only incoherent pairs sofar

no material in tracker

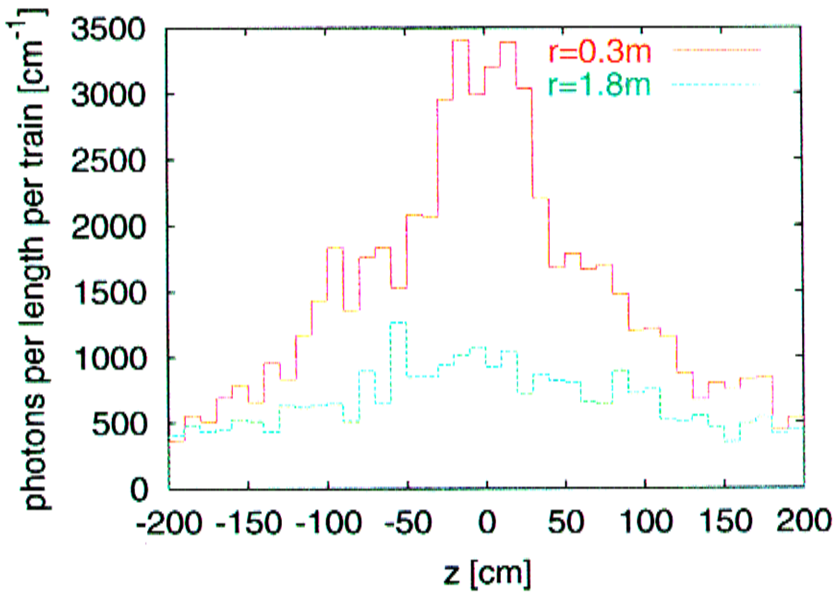
calorimetre stops particles, no backscattering

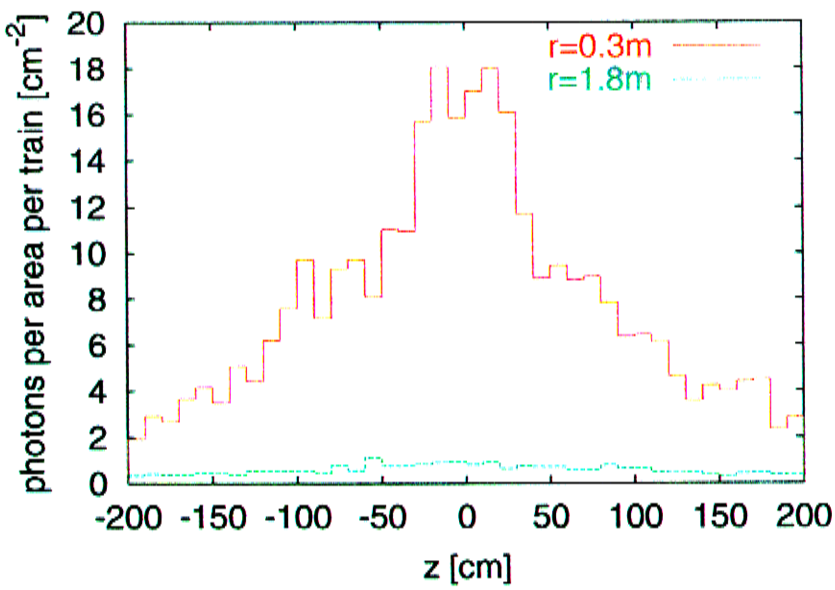
statistics too bad for charged tracks

but good enough for photons

geometry may change

Hit Densities





Hadrons

Hadrons can be produced by photon-photon collision

they can overlay interesting events

cross section is not measured at high energies

$\Rightarrow$ use parametrisation
here G. A. Schuler and T. Sjöstrand (pessimistic version)

$$\sigma_H = 211\,\mathrm{nb} \cdot \left(\frac{s}{\mathrm{GeV}}\right)^{\epsilon} + 297\,\mathrm{nb} \cdot \left(\frac{s}{\mathrm{GeV}}\right)^{-\mu}$$

$\epsilon = 0.0808,\ \mu = 0.4525$

$E_{cm} \geq 5\,\mathrm{GeV}$

E_{cm}	[TeV]	0.5	1.0	3.0	5.0
N_H		0.047	0.28	4.05	9.6

one may have to integrate over some bunch crossings

events are produced with PYTHIA

$\Rightarrow$ HADES

HADES

Library to access background files

comes with hadronic background files for CLIC at $E_{cm} = 3\,\mathrm{TeV}$

generation of background files

- initial states are generated with GUINEA-PIG
- background events are simulated with PYTHIA

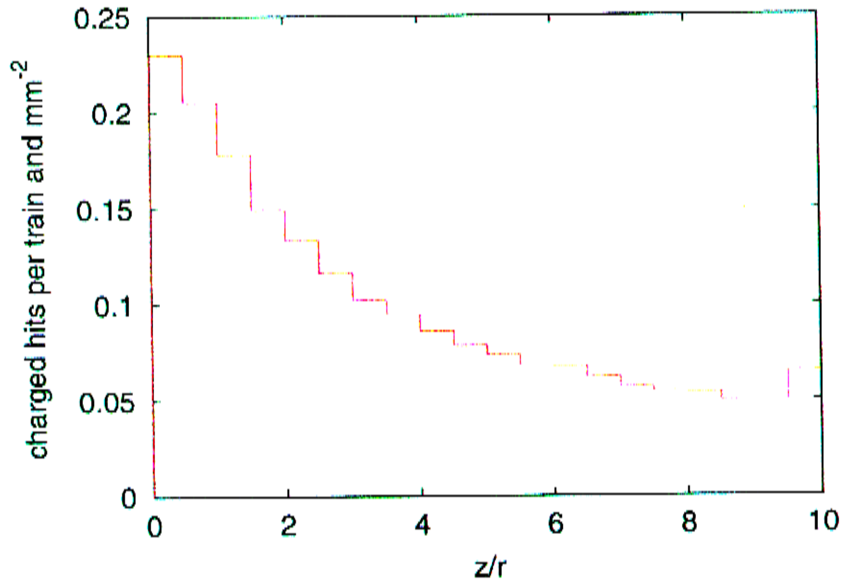
  (more generators should be included here)
- background is stored in data base
- it can be loaded into PYTHIA

included in CLIC version of SIMDET

example:

```
call hades0(iounit,'clic.01/hadron.events',
.         4.05d0,0.d0,0.d0)
...
call pyevnt
call hades
...
```

Event Properties



Cut in angle $\theta_0 = 120(40)\,\mathrm{mradian}$

no cut in transverse momentum, $[p_\perp > 0.5\,\mathrm{GeV/c}]$

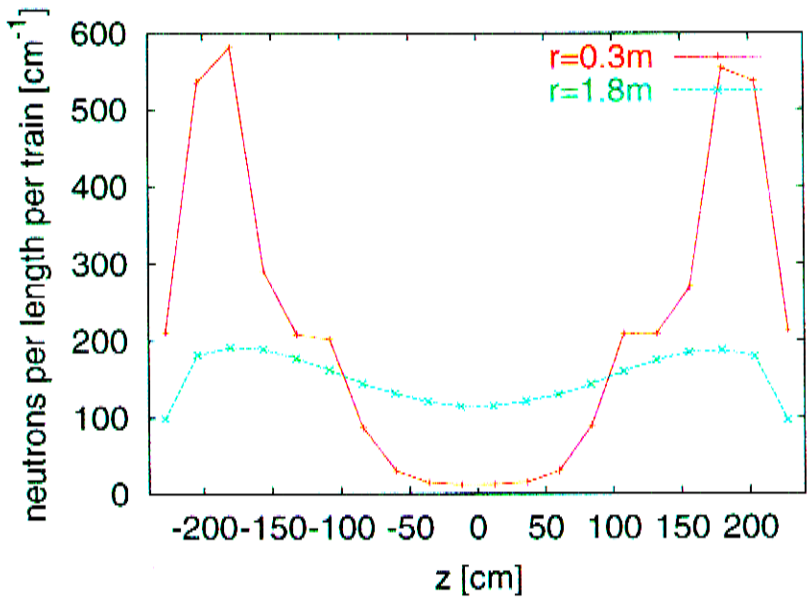
average visible energy per bunch crossing: $90(229)[42]\,\mathrm{GeV}$

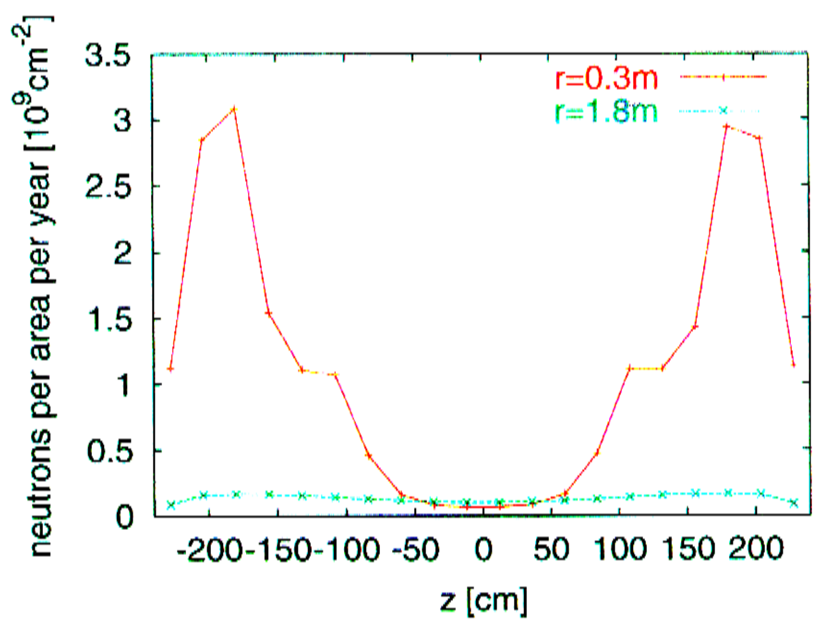
average missing transverse momentum: $2.5(2.0)[2.4]\,\mathrm{GeV}$

average charged multiplicity per crossing: 44 (59) [12]

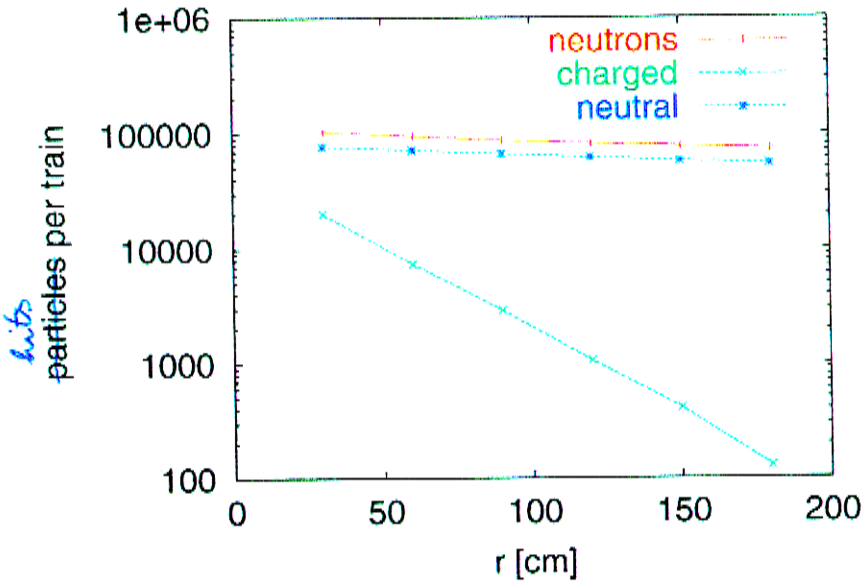
average total multiplicity per crossing: 94 (125) [18]

Neutrons in the Central Tracker





Hadronic Background in the Central Tracker



Full GEANT simulation

events from HADES with PYTHIA

no cavity effect included

2000 bunch crossing simulated

⇒ density of charged particles drops quickly with radius

Feedback

Thanks to
M. Breidenbach, P. Emma, J. Frisch,
G. Haller, T. Raubeheimer, P. Tennenbaum

Offsets of the beams in the IP are one of the main sources of luminosity loss

$\Rightarrow$ try to avoid them

$\Rightarrow$ try to correct them

the vertical is more affected than the horizontal ($\sigma_x^* \gg \sigma_y^*$)

position offset leads to strong deflection of beams

$\Rightarrow$ good signal for feedback

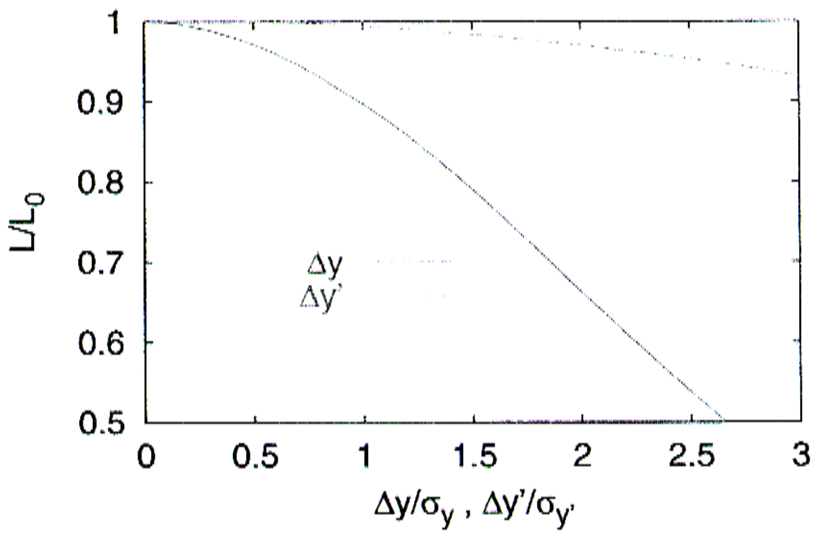
angle offsets cause

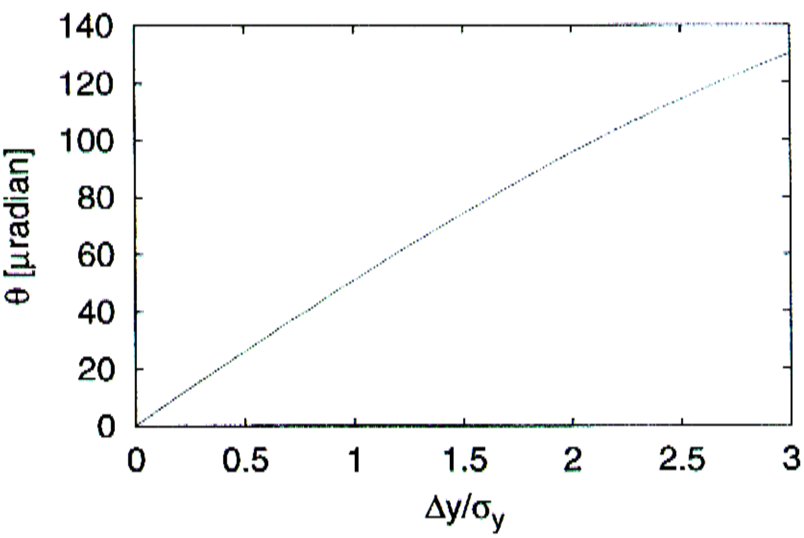
direct luminosity loss

angles of the spent beams

$\Rightarrow$ can confuse measurement

Effect of Offsets





parameters for $E_{cm} = 1\,\mathrm{TeV}$ are used

⇒ CLIC is not very sensitive to angle errors ($\beta_y^* \gg \sigma_z$)

Generic Feedback Layout

Speed is crucial

⇒ use strip-line kicker

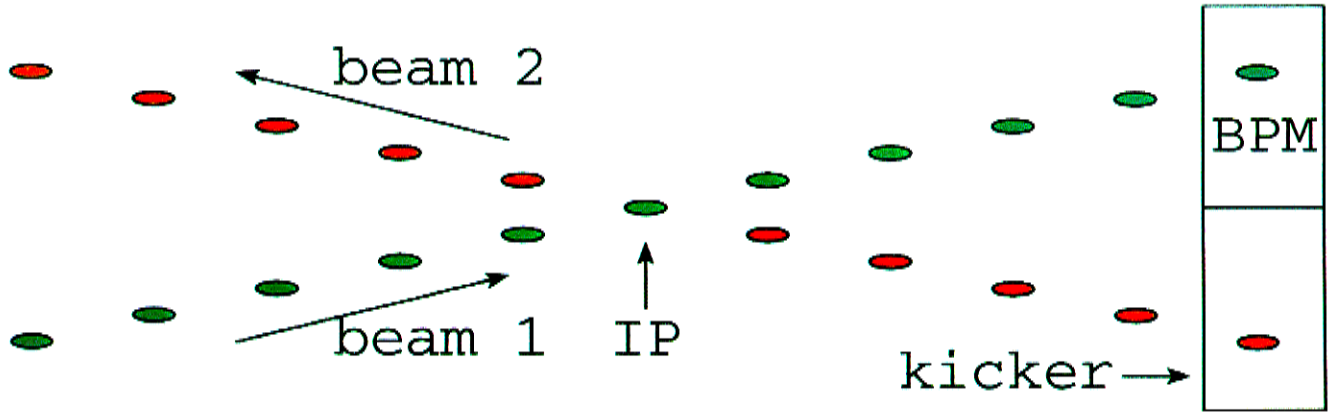
⇒ measure and correct on the same side

latency is

$$\tau_t = \tau_p + \tau_k + \tau_{fp} + \tau_{fk} + \tau_s$$

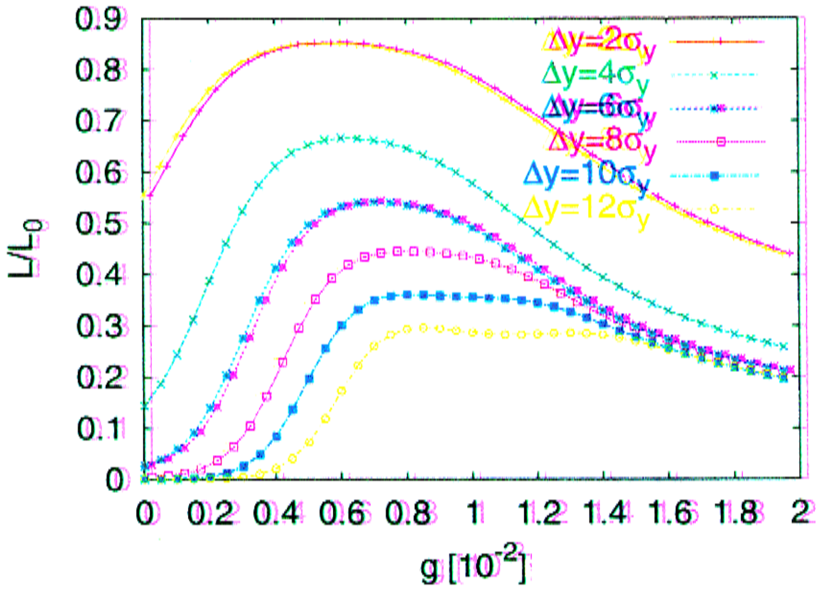
assumption in the following

$$\tau_t = 20\,\text{ns}$$



hardware test are planned (Ph. Burrows et al.)

Large Offsets



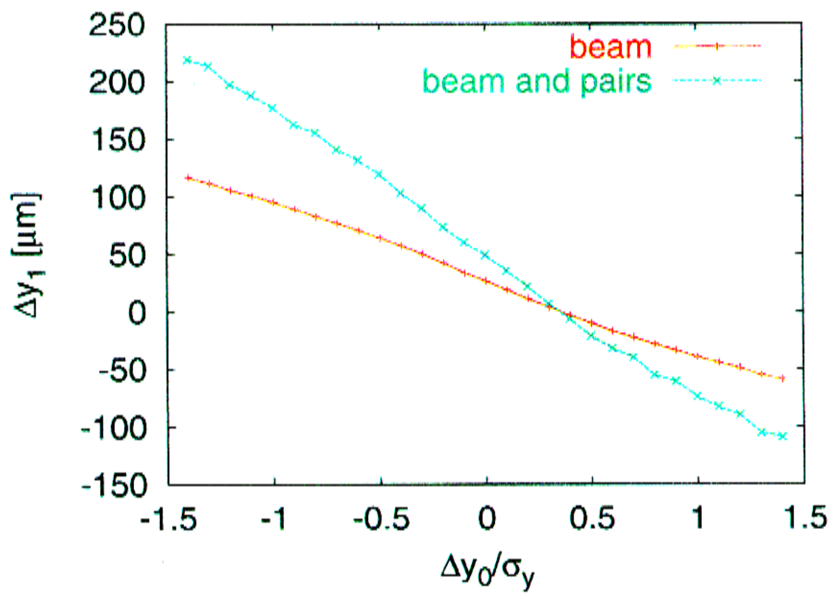
only luminosity with $E_{cm} > 0.99 E_{cm,0}$ is considered

for large offsets a slightly larger gain is advantageous

for $\Delta y = 2\sigma_y$ (and smaller) luminosity loss is reduced by factor 3

for $\Delta_y = 6\sigma_y (\approx 10\,\mathrm{nm})$ luminosity is increased from $2.6\,\%$ to $55\,\%$

Feedback at High Energy



coherent pair creation leads to significant number of particles ($\approx 20\,\%$ of the beam)

particles lose significantly in energy

⇒ deflection by the field of the solenoid becomes important

⇒ backgound hits on the BPM may be a problem

⇒ more work to be done before we can draw conclusions

⇒ but not hopeless

Conclusion

preliminary final focus system design exists

coherent pair creation determines crossing angle

- multi-bunch kink instability, exit hole

luminosity spectrum can be included in event generators (CALYPSO)

- simplified version under development

vertex detector radius $\approx 3\,\mathrm{cm}$ ($B_z = 4\,\mathrm{T}$)

- backscattering seems under control

outer mask angle $120\,\mathrm{mradian}$

lowest tag angle $40\,\mathrm{mradian}$

hadronic background is simulated

- correction to the hit density in the vertex detector
- can be included in event simulations (HADES)

intra-pulse interaction point feedback is under investigation

- looks promising sofar