Tracking Detector Optimization

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on behalf of the CLIC physics and detector study

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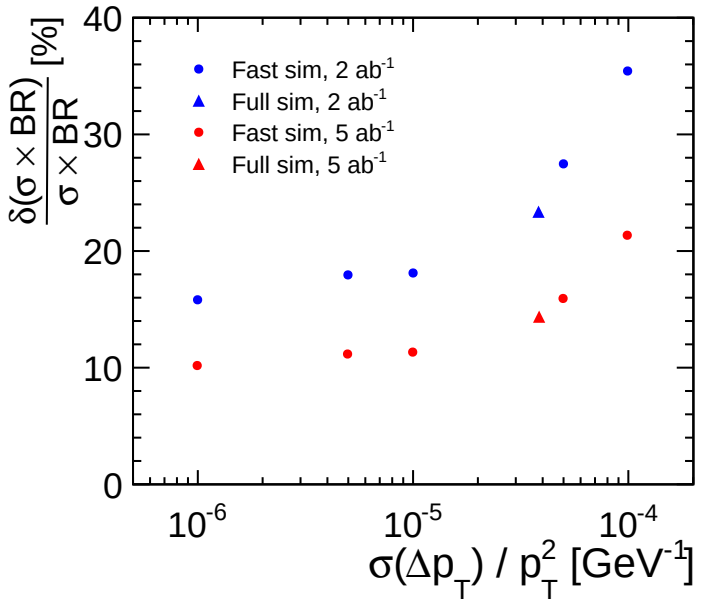
Why we need excellent momentum resolution?

- Motivated by requirements of leptonic final states
  - Higgs recoil measurement: reconstruction of $Z \to e^+e^-$ and $Z \to \mu^+\mu^-$
  - Measurement of $H \to \mu^+\mu^-$
  - Slepton production
- Goal: $\sigma(p_T)/p_T^2 \approx 2 \times 10^{-5}\text{GeV}^{-1}$

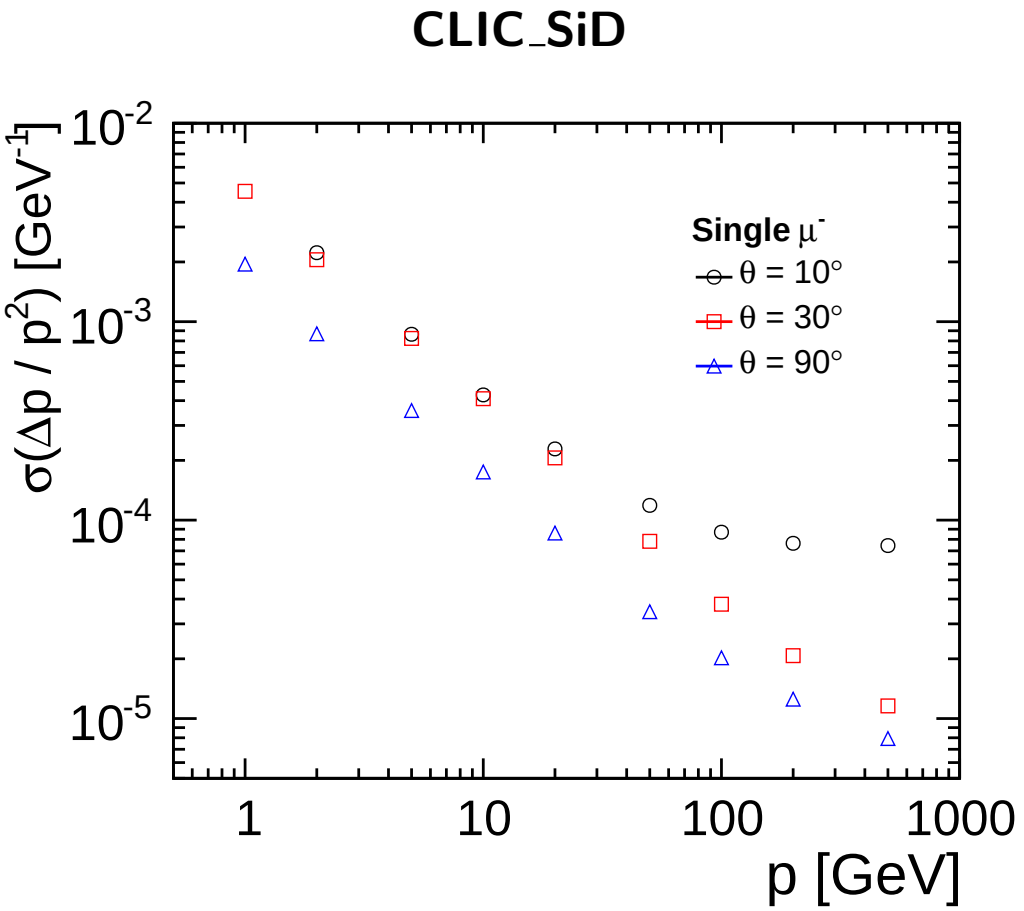
$H \to \mu^+\mu^-$ at 3 TeV



- Momentum resolution determined by magnetic field B, point resolution $\sigma(r\phi)$, lever arm S and number of measurements N
- Glückstern formula:

$$\frac{\sigma(p_T)}{p_T} \approx \sqrt{\frac{720}{N+4}} \frac{\sigma(r\phi)p_T}{0.3\ B\ S^2} \frac{\text{T m}}{\text{GeV}}$$

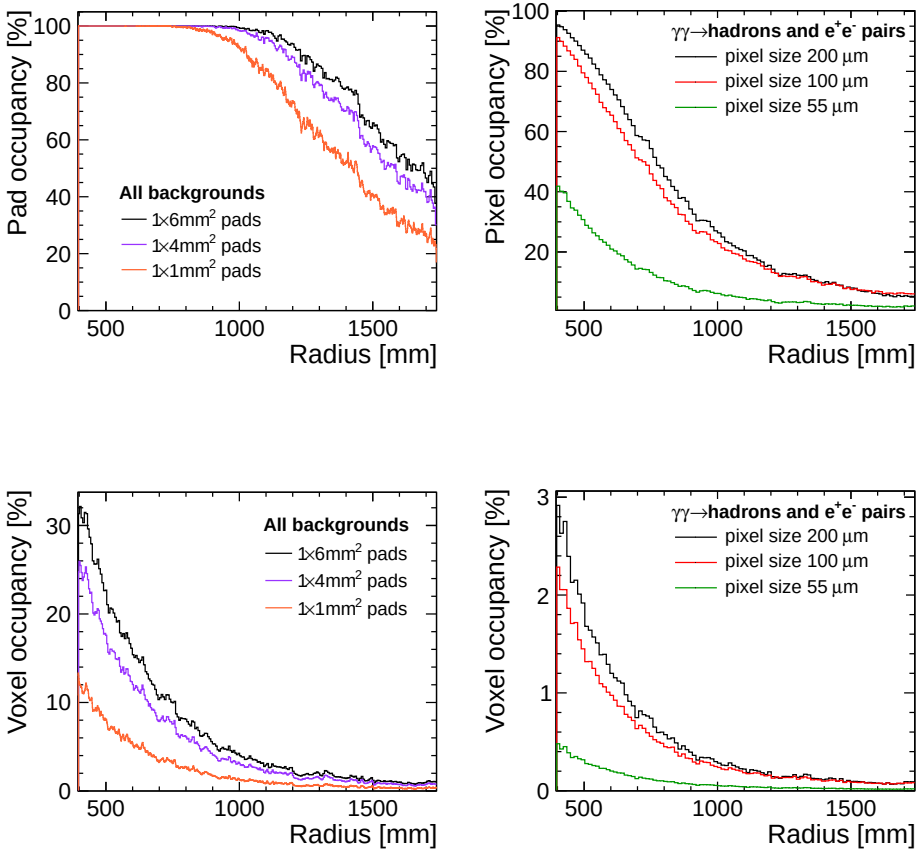
Momentum resolution



- Momentum resolution goal reached for high momentum tracks in the central region
- Multiple scattering term dominates up to highest momenta
- Could we relax some of the parameters, i.e. B field?

TPC Occupancies

- TPC readout integrates over full bunch train
- Voxel occupancies reach $> 10\%$ for inner radii with pad readout
- Pixel readout could mitigate the occupancy problem



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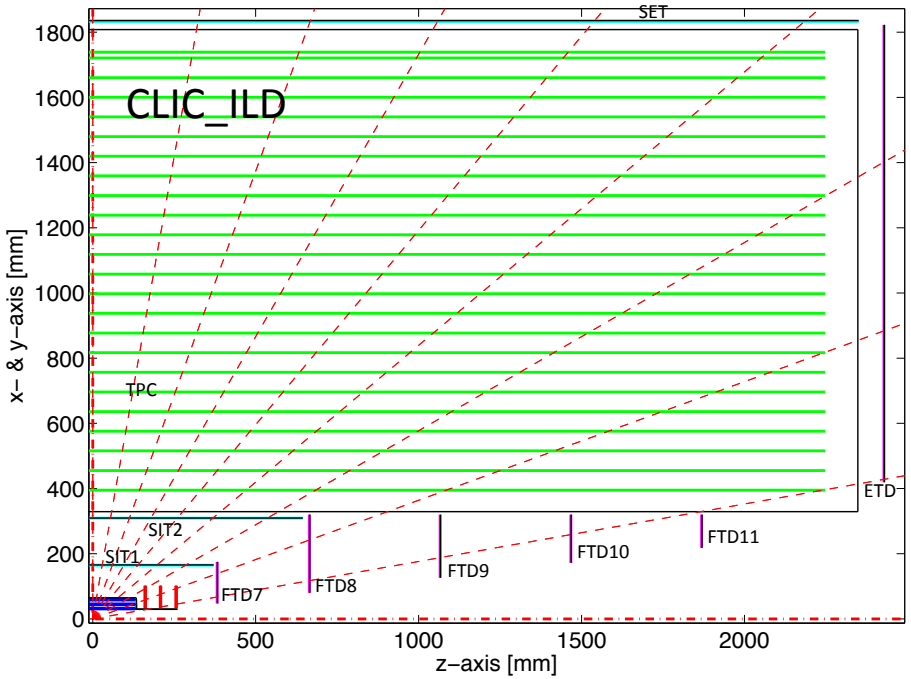
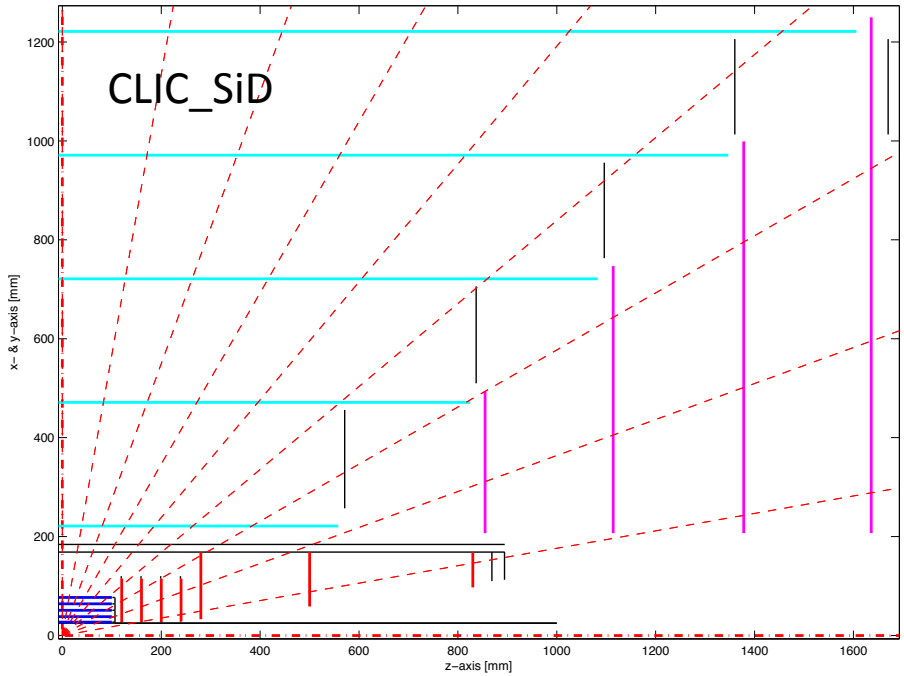
Tracker Layout





- Hermetic coverage down to the beam pipe
- Ideally equally spaced measurement points

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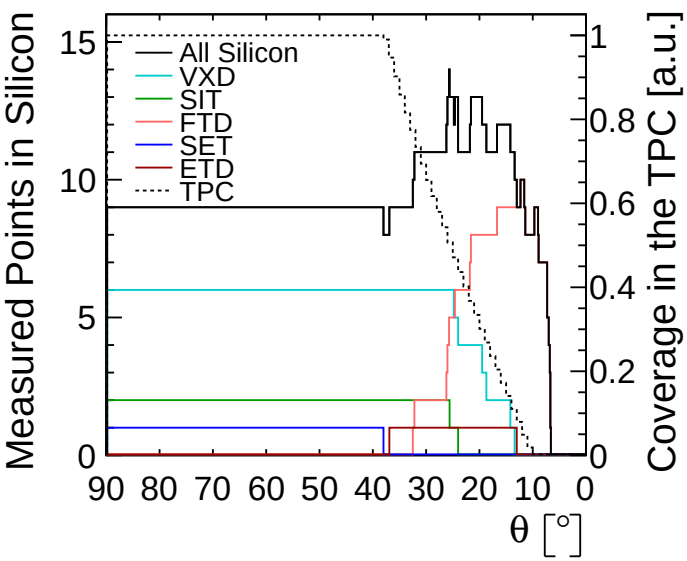
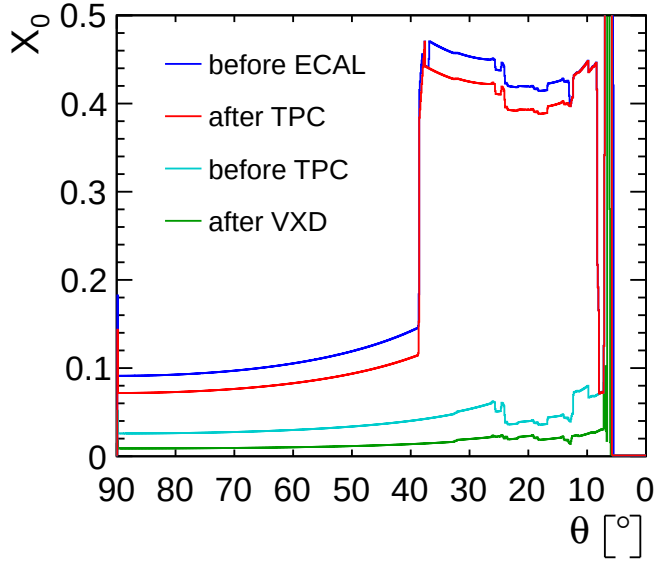
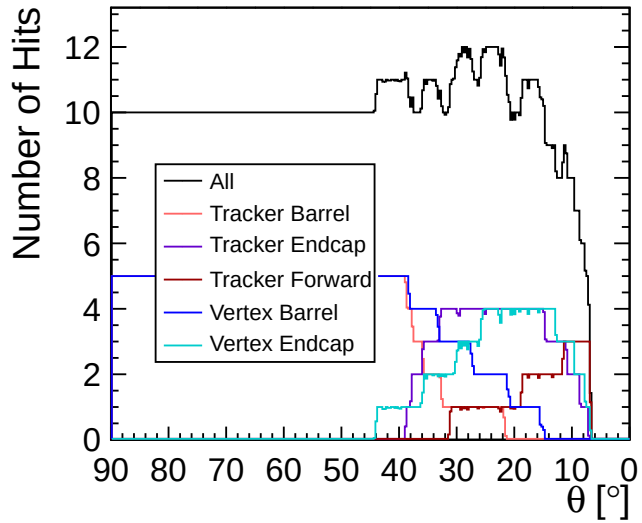
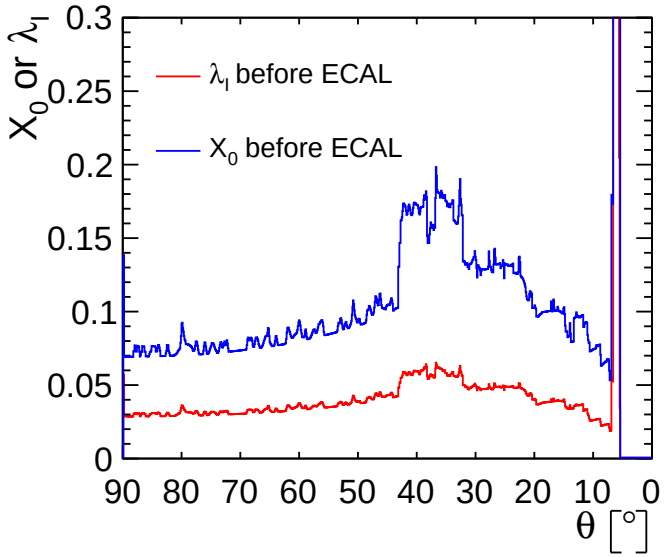
CLIC_ILD





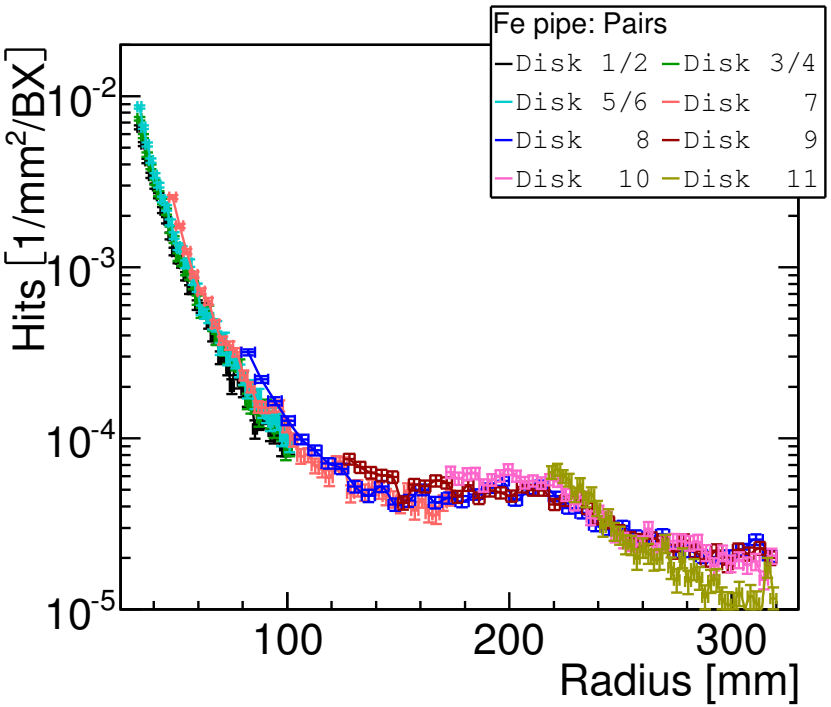
CLIC_SiD

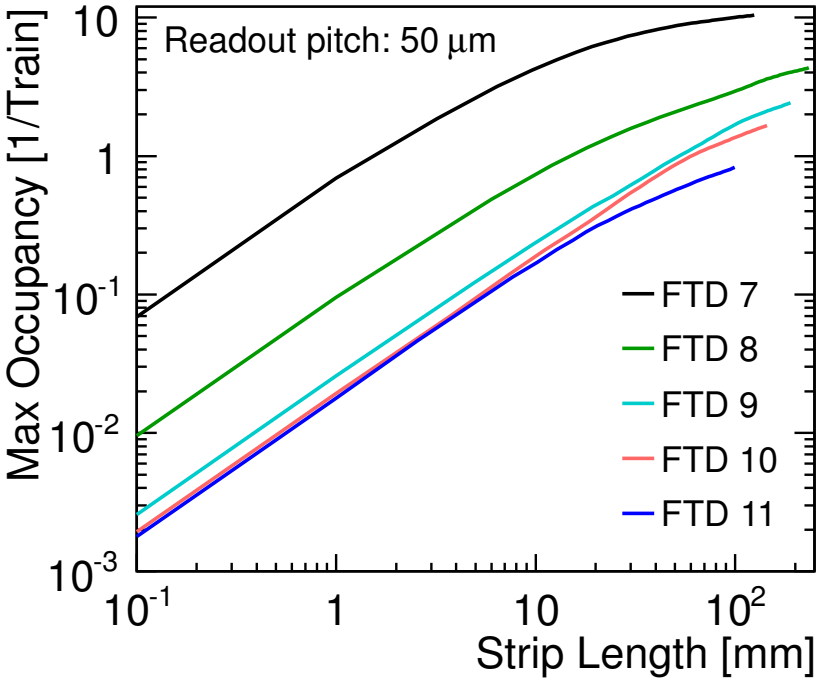




Occupancies

CLIC_ILD forward tracking disks





- Occupancy problematic for strip detectors in forward region
- Use large pixels or strixels instead - no stereo strip layers

LCD-Note-2011-021

	time stamping resolution [ns]	time sampling period [ns]	cell size [mm^2]	number of channels [10^6]	average to maximum occupancy [%]	number of bits per hit [bit]	data volume [Mbyte]
VTX barrel	~ 5	10	0.02×0.02	945	< 1.5 - 1.9	32	56
VTX endcap	~ 5	10	0.02×0.02	895	< 2.0 - 2.8	32	72
FTD pixels	~ 5	10	0.02×0.02	1570	0.1 - 1.0	32	6.3
FTD strips	~ 5	10 - 25	0.05×100	1.6	160 - 290	16	48
SIT	~ 5	10 - 25	0.05×90	1.0	100 - 174	16	30
SET	~ 5	10 - 25	0.05×438	5.0	17 - 17	16	150
ETD	~ 5	10 - 25	0.05×300	4.0	38 - 77	16	120
TPC	–[a]	25	1×6	3[b]	5 - 32	24	500
ECAL barrel	1	25	5×5	69.5	< 3	16	2090
ECAL endcap	1	25	5×5	43.2	60 - 150	16	1300
HCAL barrel	1	25	30×30	6.9	< 5	16	210
HCAL endcap	1	25	30×30	1.8	120 - 5200	16	54
HCAL rings	1	25	30×30	0.2	< 5	16	6.0
LumiCal	5	10	5×5	0.2	600 - 6000	32	28
BeamCal	5	10	8×8	0.1	15600[c]	32	15
MUON barrel	1	25	30×30	1.4	0.01 - 0.05	24	< 0.01
MUON endcap	1	25	30×30	2.4	0.12 - 10	24	< 0.01

[a] By combining with different subdetectors in offline reconstruction 2 ns will be achieved.
[b] The 3D TPC reads out 1000 voxels per channel for each bunch train.
[c] All cells measure a signal for each bunch crossing.

Tracking software

Digitization

- Need realistic simulation of charge collection and readout in silicon detectors and hit clustering
- Make use of the SiSim package in `org.lcsim`: noise, charge generation, etc.
- Include experience from pixel R&D

Track finding and track reconstruction

- SeedTracker algorithm in `org.lcsim` is very flexible but too simplistic $\rightarrow$ need a Kalman filter
- trf (D0 tracking), AIDA Tracking toolkit, MarlinTrk
- How does the full overlay (including pairs) affects pattern recognition
- Impact of realistic magnetic field map - need Runge-Kutta stepper?
- Include first ECAL layer in track reconstruction to improve z resolution in case of barrel strip option
- Calorimeter assisted tracking to recover late decays in all silicon option

Engineering aspects

- Which technology options to reach the desired segmentation goals
- Is air cooling feasible?
- Realistic estimate of required services and cabling
- Is the current amount of support sufficient?
- How realistic are 0.5–1% X/X_0 per layer in the main tracker?