Vertex detector R&D for CLIC

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on behalf of the CLICdp collaboration

Compact Linear Collider

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CLIC

e^+e^- collisions

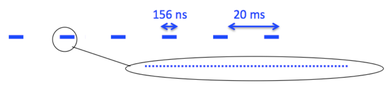
~350 GeV < √s < 3 TeV (staged construction/operation)
high luminosity

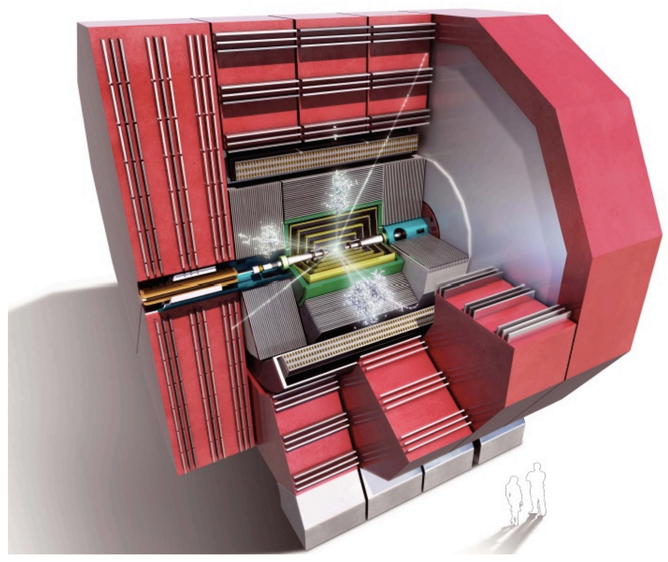
	CLIC at 3 TeV
L ($cm^{-2}s^{-1}$)	5.9×10^{34}
BX separation	0.5 ns
#BX / train	312
Train duration (ns)	156
Rep. rate	50 Hz
Duty cycle	0.00078%
σ_x / σ_y (nm)	≈ 45 / 1
σ_z (μm)	44

Drives timing requirements for CLIC detector

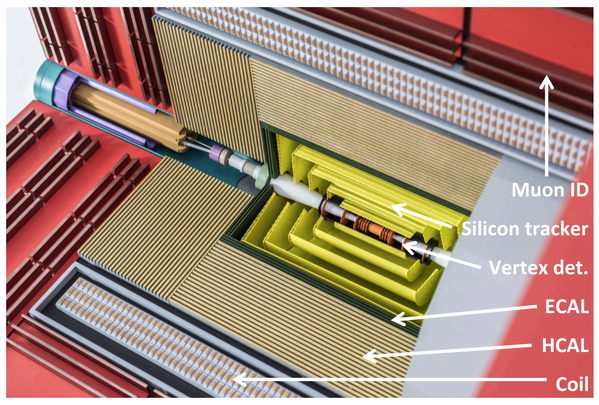
very small beam size

CLIC bunch structure (not to scale)

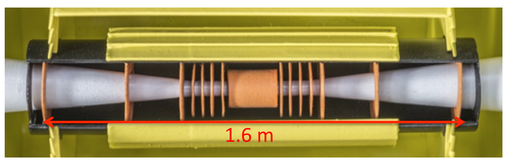




CLIC experiment



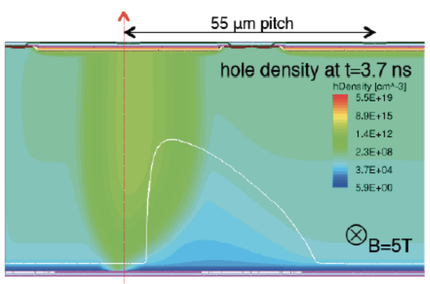
CLIC vertex detector



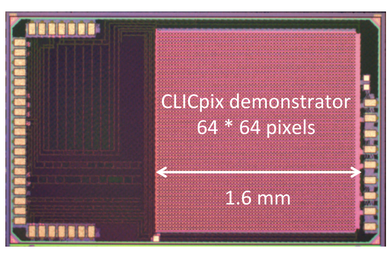
Aim: good flavour tagging in high occupancy
~25×25 μm pixel size => ~2 Giga-pixels

- inner radius ~30 mm
- maximum occupancy 3%
- 0.2% X_0 material per layer <= very thin !
  - thin ASIC + sensor (50 μm+50 μm)
  - low-power design, power pulsing, air cooling => aim: 50 mW/cm²
- time stamping 10 ns
- radiation level ≈ 10^4 *lower* than LHC

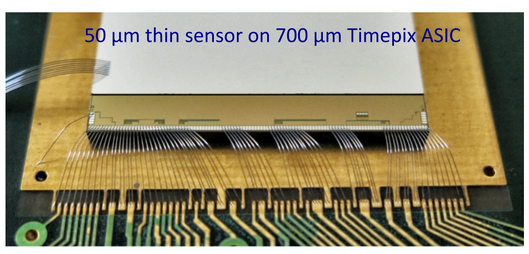
CLIC vertex R&D activities (based on two hybrid technology technologies)



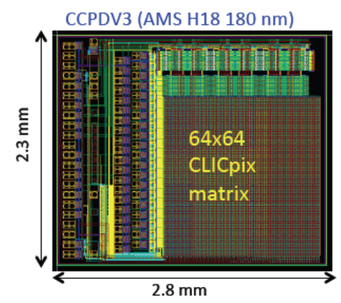
TCAD sensor simulation
Spread of charge cloud in p-in-n sensor in 5 tesla B-field



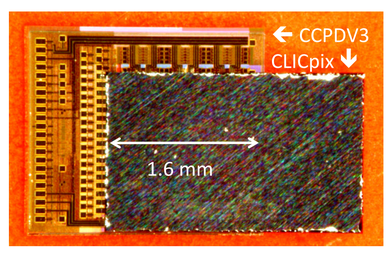
Fully functional ASIC in 65 nm technology
25 μm * 25 μm pixels
4-bit ToA for <10 ns time stamping
4-bit ToT pulse height (for charge sharing)



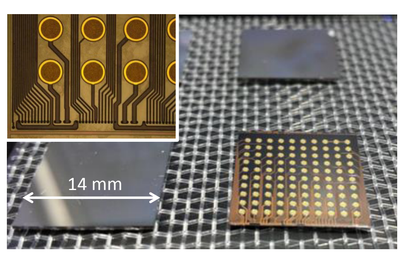
R&D on **thin sensors with slim edges** for minimal material and minimal dead areas; beam tests of Timepix ASIC assemblies and thin sensors (50 μm – 500 μm)



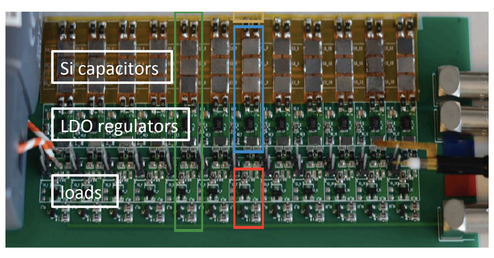
Active HV-CMOS sensor
(CCPDV3) with CLICpix footprint (sensor + 2 amplifier stages)



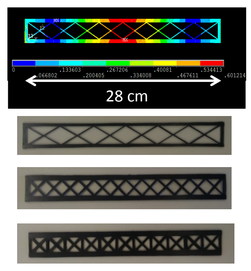
AC-coupled (glue) **assembly of CCPDV3 and CLICpix demonstrator**



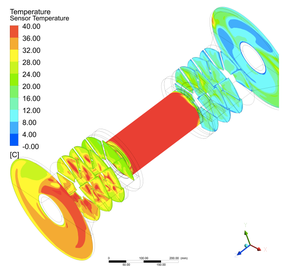
R&D **on Through-Silicon Vias (TSV)**
=> possibility for 4-side buttable chips
Successfully applied on Medipix3RX ASIC;
TSV production on thinned Timepix ongoing



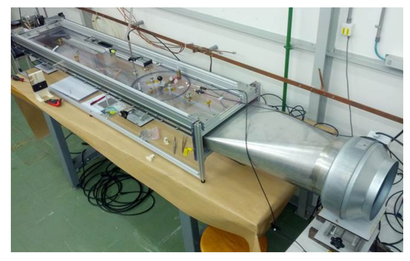
Low-mass power pulsing tests, based on controlled current source combined with local capacitive storage and low drop-out regulators (0.104% X_0/layer, prospects for 0.043% X_0/layer)



R&D on **low-mass module supports**
0.06% X_0 per double-layer support



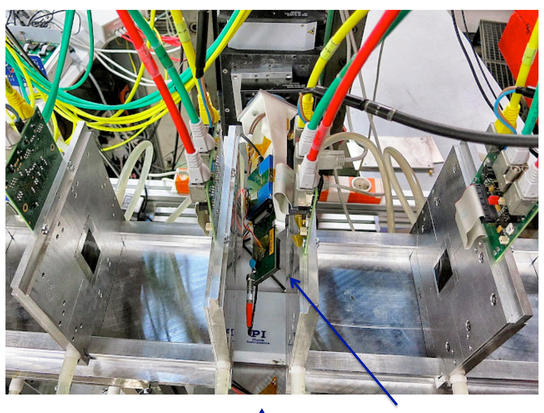
Air cooling simulations of the vertex detector region



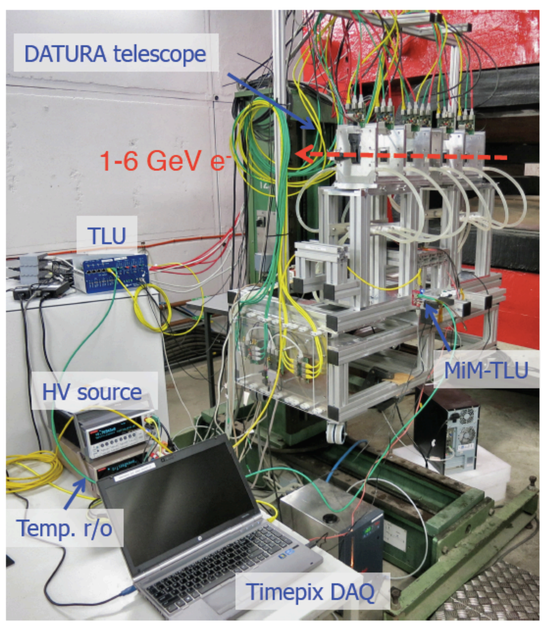
Laboratory studies of **heat dissipation, air cooling and vibration characteristics**

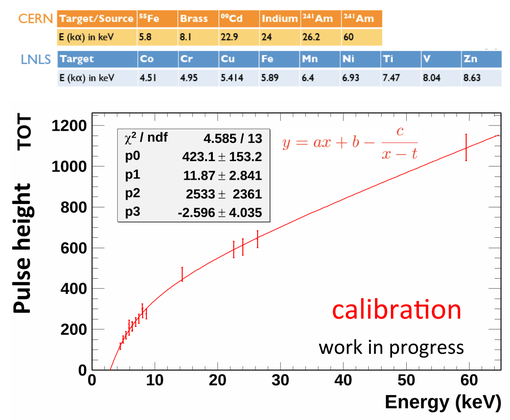
Tests of detector assemblies with Timepix ASICs and thin sensors

Sensor thickness: 50 μm, 100 μm, 150 μm, 200 μm and 500 μm
Type: p-in-n and n-in-p; slim edge (250-450 μm) and active edge (20-50 μm)
ASIC thickness: 100 μm, 700 μm
Overall thinnest assembly: 100 μm on 100 μm

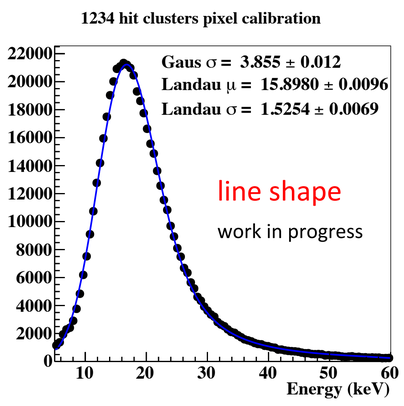


Test beam set-up at DESY
Electron beam 1-6 GeV
Data taken in 2013-2014

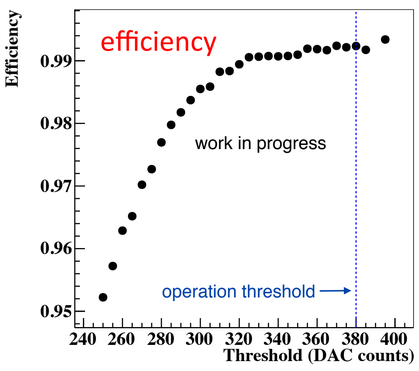




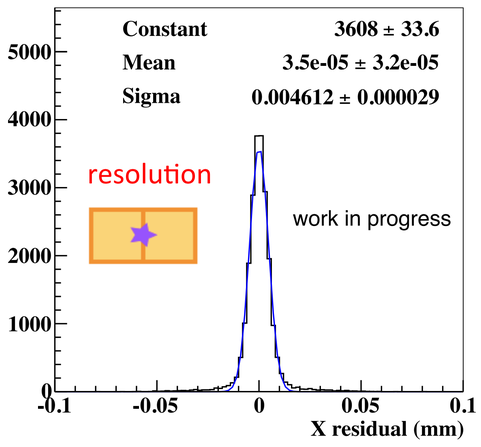
Global and pixel-by-pixel calibration with various radioactive sources and X-ray fluorescence (CERN) and calibrated X-ray beams (LNLS, Brazil); global calibration of a 100 μm sensor assembly shown.



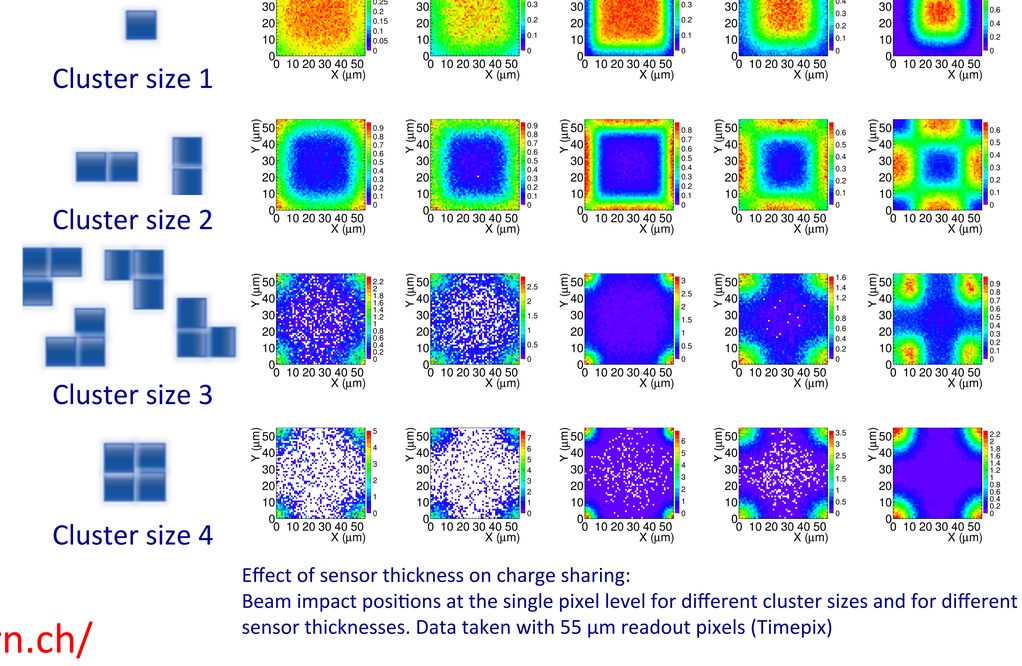
Landau + Gauss fit, 1-4 hit clusters, 50 μm p-in-n sensor, pixel-by-pixel calibrated.



Particle detection efficiency versus threshold setting for the 100 μm on 100 μm p-in-n assembly



Residual $X_{telescope}$-X_{DUT} for 2-hit cluster case, taking into account non-linear charge sharing, 50 μm thin sensor in 5.6 GeV electron beam. Unfolding the 3.2 μm telescope resolution yields DUT resolution of 3.3 μm.



Effect of sensor thickness on charge sharing:
Beam impact positions at the single pixel level for different cluster sizes and for different sensor thicknesses. Data taken with 55 μm readout pixels (Timepix)

http://clicdp.web.cern.ch/