New ideas on detector technology for the ILC experiments

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ILC environment

- → $\sqrt{s} = 250$ GeV (upgrades to 1 TeV) extendable
- → Instantaneous Luminosity $1.35 \cdot 10^{34}$ cm^{-2}s^{-1} ($\sqrt{s} = 250$ GeV)
- → Push-pull system for detectors
- → 5-10 Hz train repetition rate enables power pulsing
- → No pile-up 0.1 hadronic e^+e^- events per bunch train
- → No hardware trigger

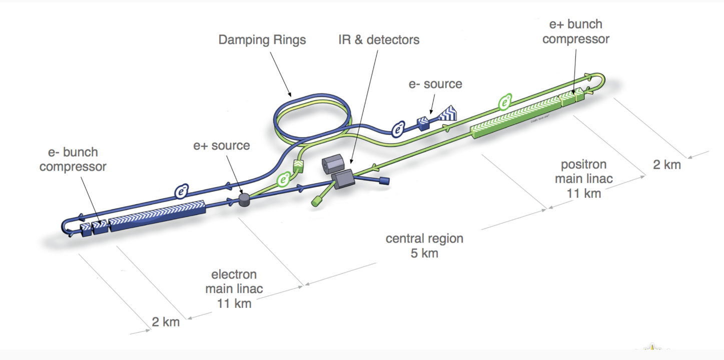


Figure 1: Schematic overview of the ILC.

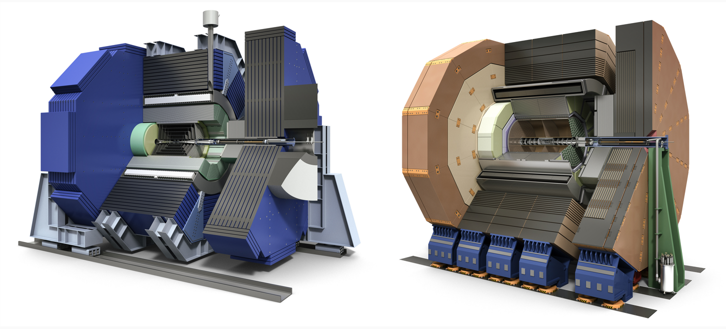
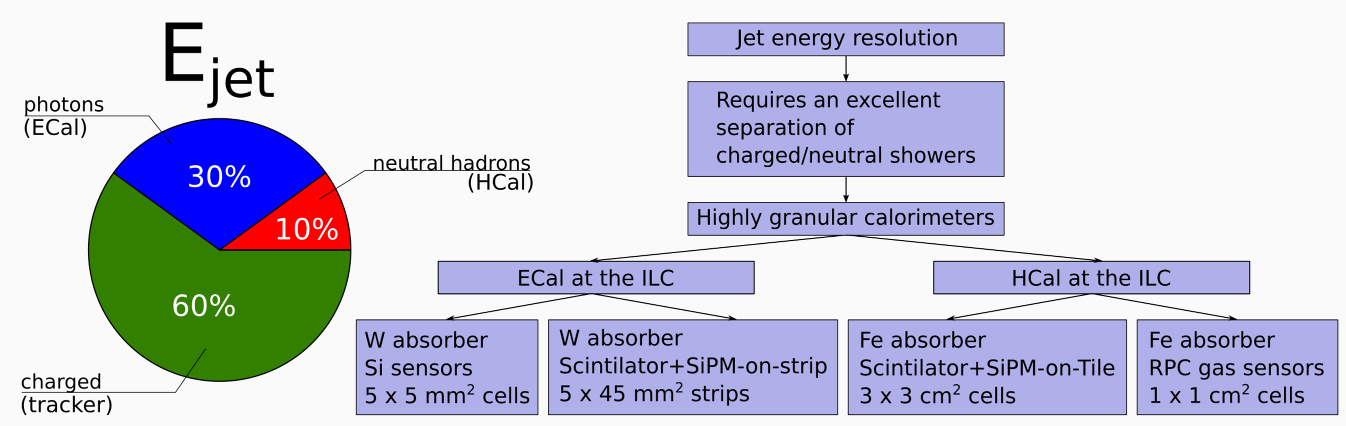
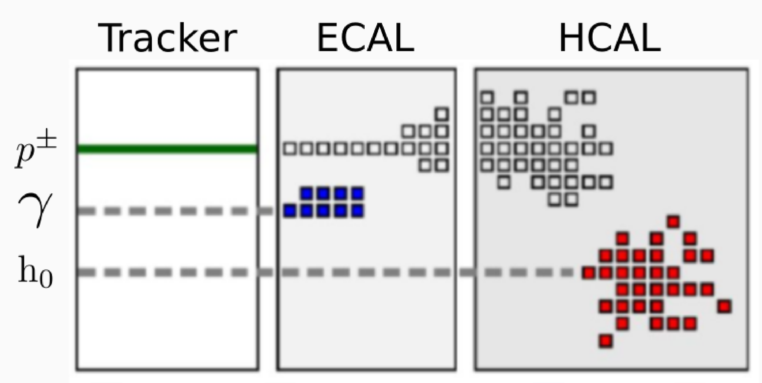


Figure 2: SiD (left) and ILD (right) detectors proposed for the ILC.

Particle flow with highly granular calorimeters





$$E_{\text{jet}} = E_{\text{charged}} + E_\gamma + E_{h_0}$$

Figure 3: Reconstruction of a jet energy using the particle flow approach.

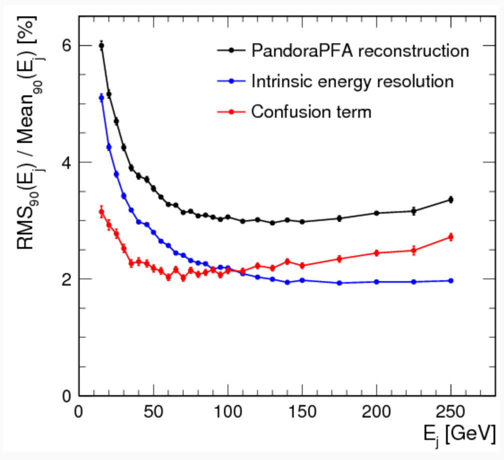


Figure 4: Jet energy resolution achievable at the ILC with the Pandora particle flow algorithm.

Forward region calorimeter for luminosity measurement

Lumical prototype

- → Luminosity measurement from low-angle Bhabha scattering
- → test-beams in 2014, 2016 and 2020
- → Effective Molière radius ≈ 8.1 mm
- → Position resolution ≈ 0.44 mm

Dedicated readout ASIC (FLAME)

- → Very low power consumption
- → fast 10-bit ADC in each channel

GaAs sensors for the BeamCal

- → Radiation hard (1.5 MGy for 8-21 MeV e^-)
- → Tracing technology allowing thin sensors

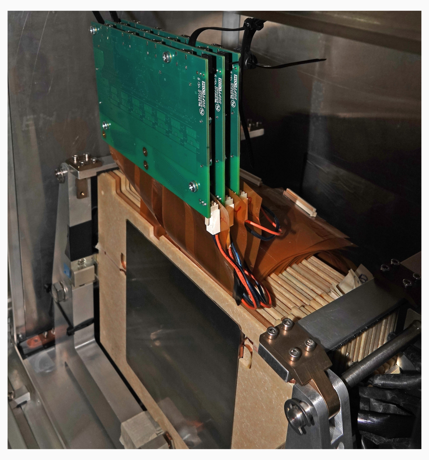


Figure 5: The LumiCal prototype during the test beam in 2020. Three first sensors are equipped with the dedicated FLAME readout boards.

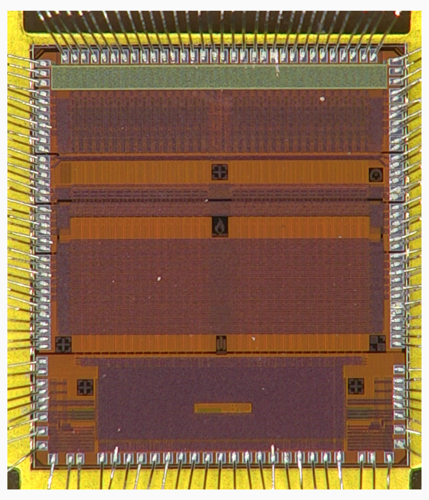


Figure 6: Photograph of the FLAME ASIC.

Extendibility

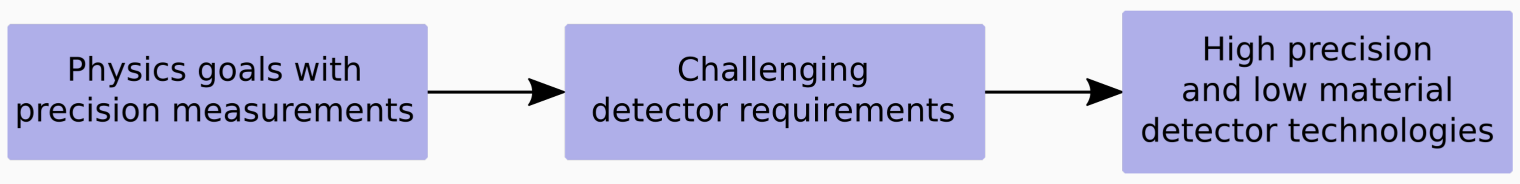
- → No synchrotron radiation at the linear colliders
- → Potential for Multi-TeV energy upgrades with the development of new acceleration technologies

Technology	ILC Nb	ILC Nb_3Sn	CLIC	PWFA DLA
Acceleration gradient	35 - 50 MV/m	120 MV/m	100 MV/m	1 GV/m
Energy	0.5 - 1.5 TeV	4 TeV	3 TeV	30 TeV

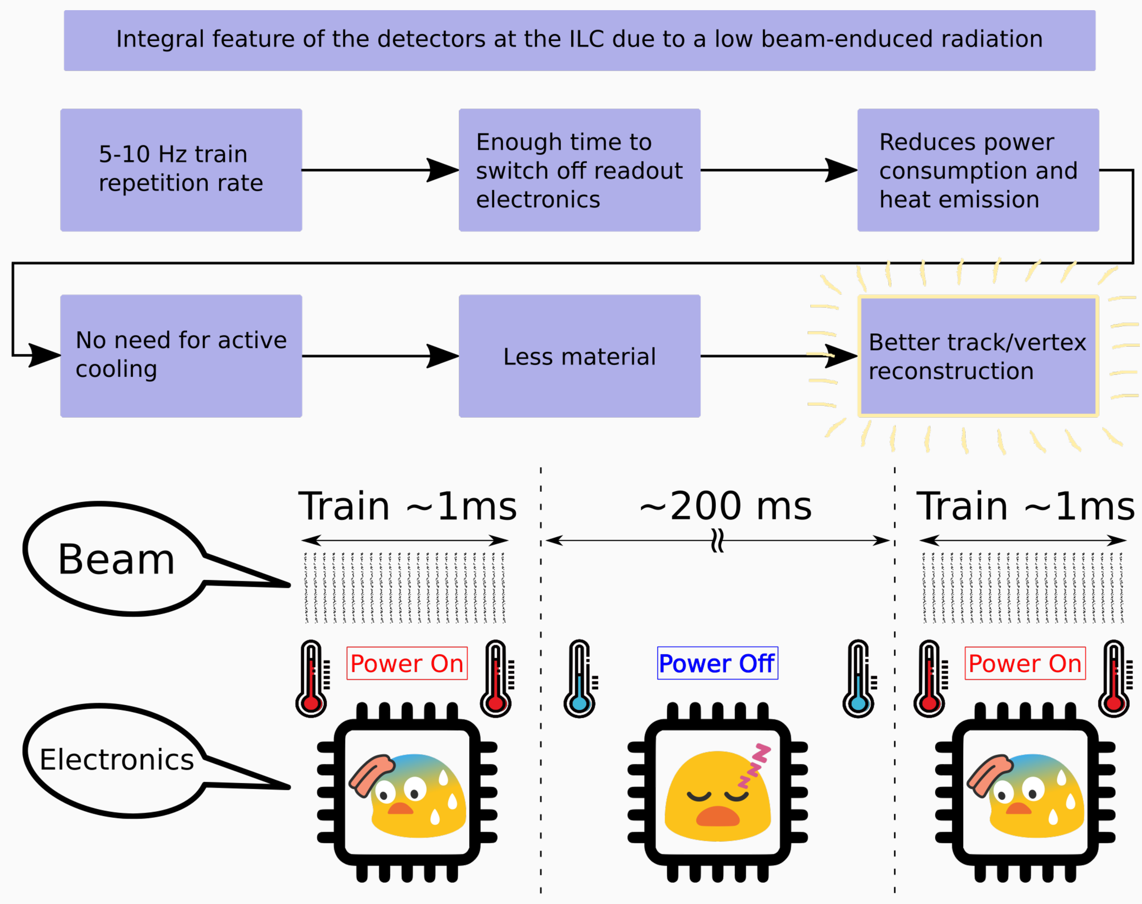
- → **Diverse** and **long-term** physics program
- → New challenges for the detector design at the ILC?

Detector performance requirements

Performance benchmark	Achievable	Needed for	Physics goals
Jet energy res.	~ 3-4 %	W/Z/t-ID	W/Z precision physics
Vertex position res.	~ 3μm	b/c/τ tagging	Higgs couplings
Track momentum res.	$2 \cdot 10^{-5}$ GeV^{-1}	Recoil mass	Higgs mass
Luminosity	~ 10^{-4}	Cross section	Higgs total width
Hermeticity	~ 6 mrad	missing 4-momentum	Dark Matter



Power pulsing



Low Gain Avalanche Detector (LGAD) Si sensors

- → Novel Si sensor technology
- → 20-30 ps time resolution is achievable
- → Considered to include in ECAL or SET of ILC detector concepts

Applications:

- → 4D (x, y, z, t) tracking
- → 5D (x, y, z, t, E) calorimetry
- → Particle ID for charged hadrons

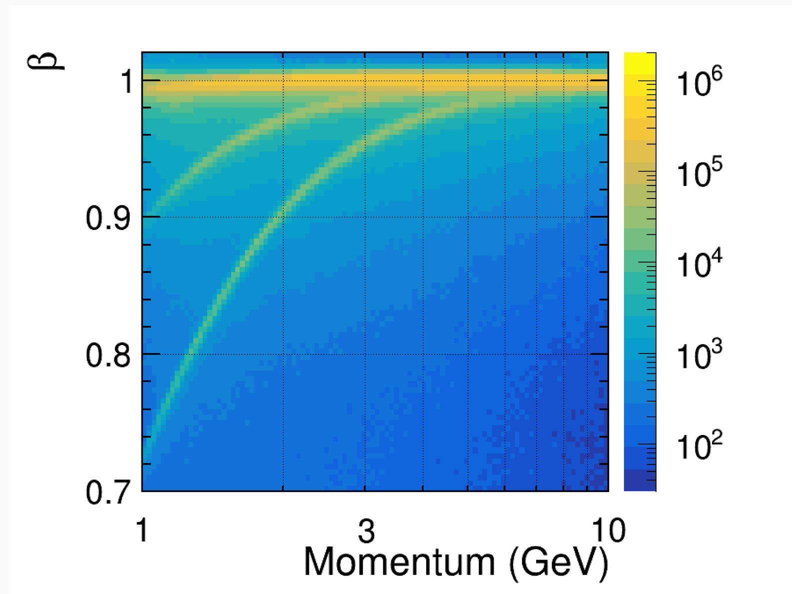


Figure 7: Relative velocity β calculated with time-of-fligh versus momentum p bands for $\pi^\pm$, $K^\pm$, p particles. Bands are distinguishable up to 4-5 GeV momentum. Time resolution of 50 ps is assumed

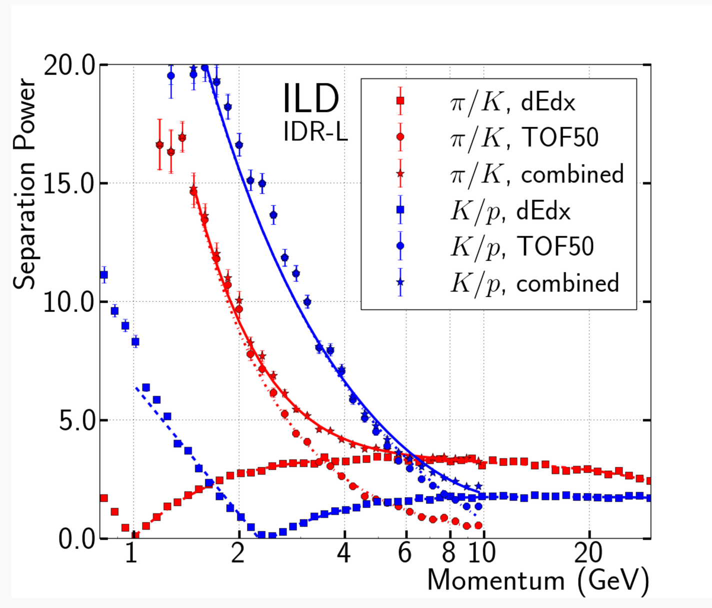


Figure 8: Separation power of time-of-flight (TOF) approach for ILD detector in contrast with dE/dx method.

Vertex decector

Vertex detector requirements:

- → 3 μm vertex spacial resolution
- → 0.12 - 0.15% X_0 material

Several technology options:

- → CMOS
- → DEPFET
- → FPCCD

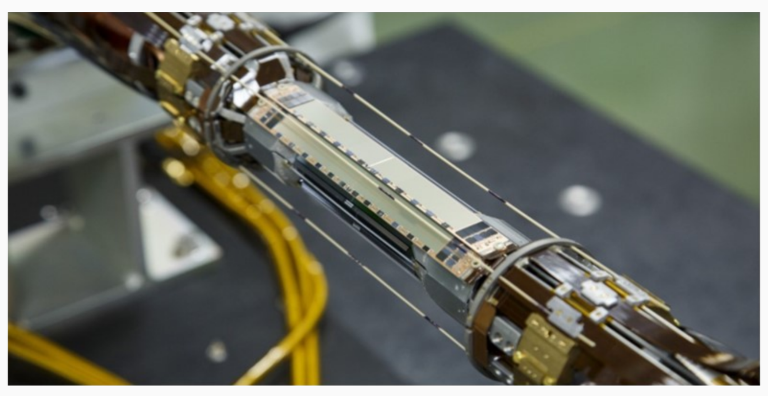


Figure 9: BELLE II DEPFET vertex detector. One of the options considered for the ILC.

ilc international development team

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