Hybrid ECAL: optimization and related developments

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Topics

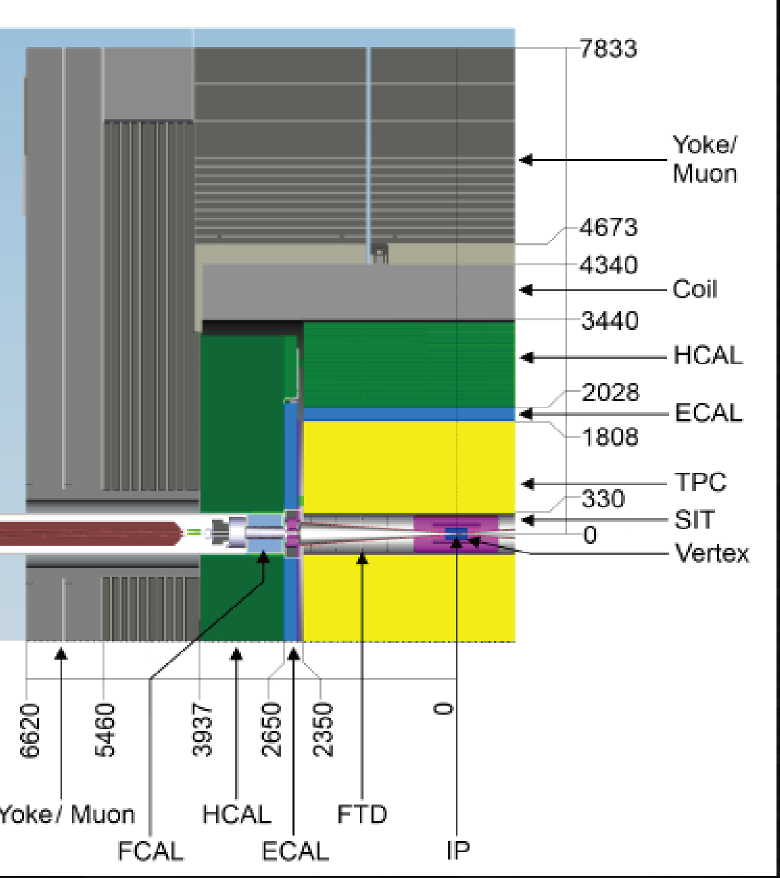
- Why hybrid?
- Optimization
- Combined DAQ
- Plans

ILD & ECAL

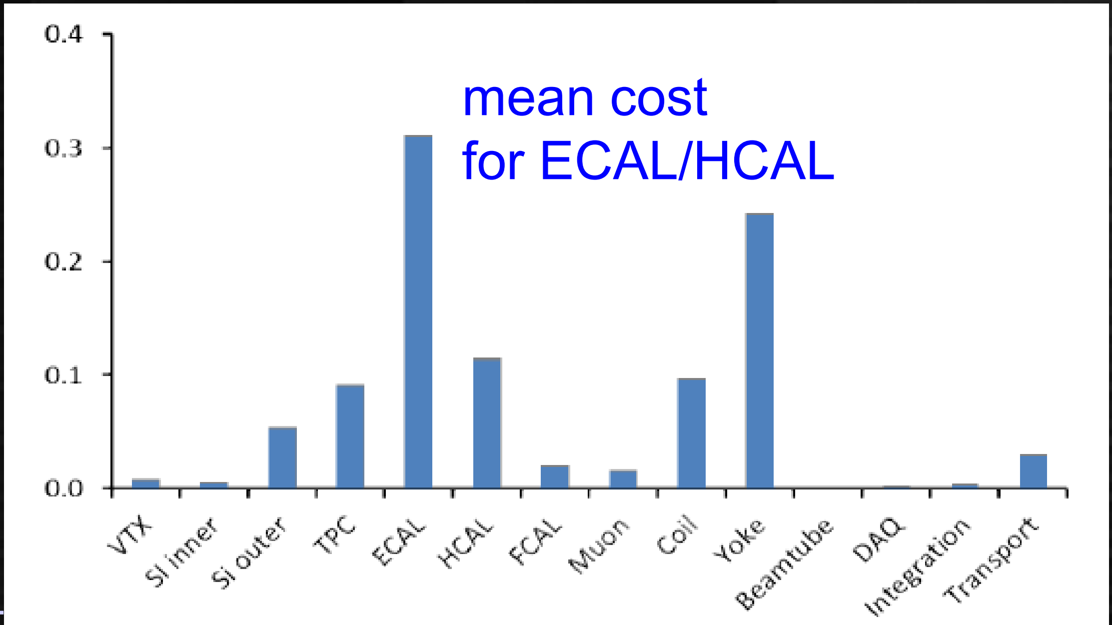
ILD: Intl. “Large” Detector

r_{ECAL} = 1800 mm (SiD: 1200 mm)

Excellent PFA power
but expensive ECAL/Yoke

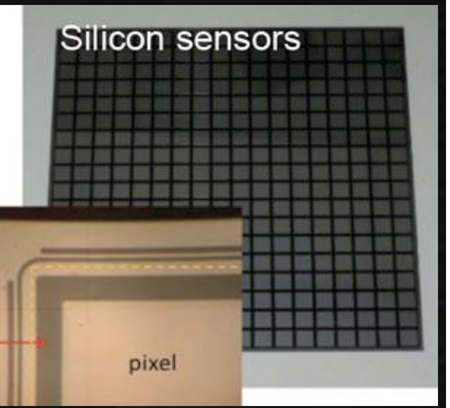


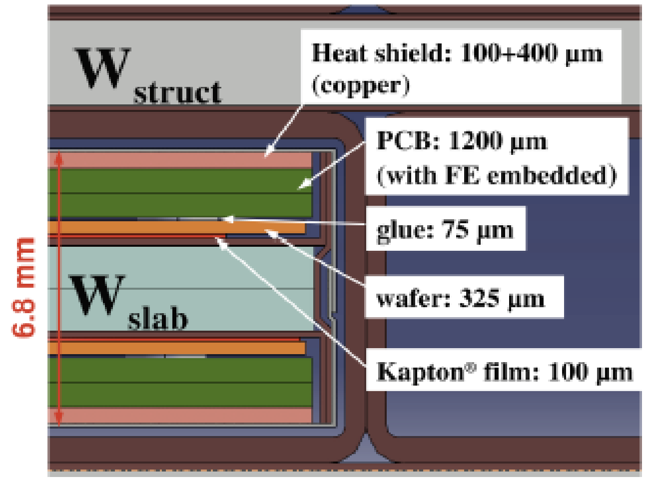
ILD cost in DBD: 391.8 MILCU in total



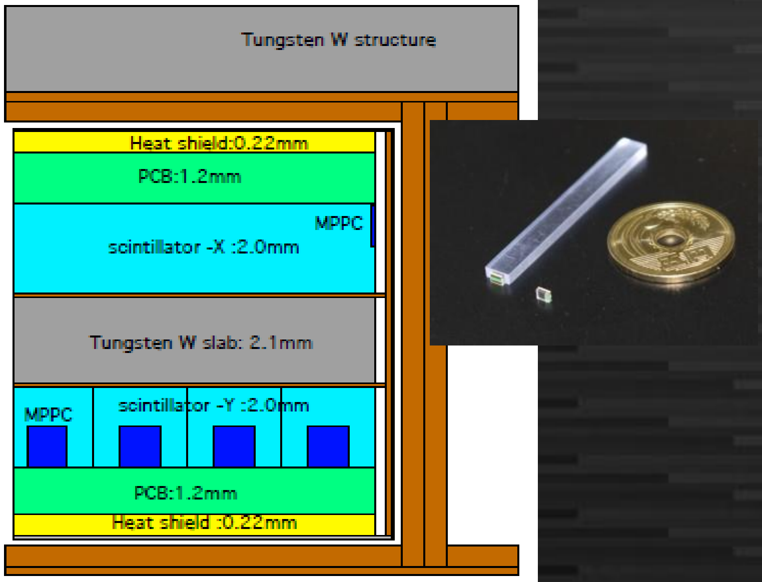
ILD ECAL: Silicon and Scintillator

SiECAL





ScECAL



Tungsten absorber + Silicon
320 μm (maybe 500 μm)
5 x 5 mm^2 pixels
256 pixels / chip
Expensive sensor

Tungsten + Scintillator strips
1 mm thick (10-20 photons)
5 x 45 mm^2 crossing strips
Each strip should be wrapped
Price is about half of Silicon
(dominated by PPD)

A comparison

V. Balagura (LLR), ILD meeting in Oshu

	Scintillator	Silicon	Comment
MIP response	7 photons	37 K pairs	Poisson fluctuation for Sc
amplification	SiPM: (2 – 3)e5	1	
Total MIP signal	(1.5 – 2)e6	40 – 60 times lower signal. Compensated by electronics gain	Electronics with lower noises is required for Si. Harder than in tracking detectors because of larger pads and associated input capacitances.
Uniformity	Optimization on-going	Close to 1	
Intrinsic linearity	SiPM saturation, asymptotic value != N pix, sometimes no asymptotic, not understood	Linear	Sc calibration in full dynamic range is required, probably per channel
Calibration	As a function of HV, temperature	Once, “forever”	Per SiPM, to be included to the cost
Stability	Monitoring of HV, T, continuous on-line calibration	Perfect	
Intrinsic xtalk	O(1%), HV dependent, MIP absolute calibration is required	Absent, except at guard ring	Continuous on-line LED calibration is not absolute
FE chip xtalk	Present	Present	Unavoidable with low power electronics, to be simulated
Automation	One strip at a time	256 pixels per sensor at a time	
Cost	1 ILCU/SiPM = 0.44 ILCU/cm2 for 0.5x4.5 strips	3 ILCU / cm2, real offer	Cost of SiPM characterization, strip wrapping, assembly is not included

Cost-conscious options

Small detector: r_{ECAL} ~ 1400 mm with silicon only

+ Robustness in ECAL, Simple
+ Cheaper not only in ECAL but also in York
- Performance degraded (both trackers and CALs) esp. 1 TeV upgrade should be a problem
- Very similar to SiD: redundancy reduced

performance
→ equivalent luminosity
→ operation cost

Hybrid ECAL (Silicon + Scintillator)

- A bit more complexity, careful calibration needed (with AHCAL complexity will be reduced)
- Cheaper only in ECAL: competitive if stray field restriction can be revisited for yoke
+ Performance degradation is very small
+ Large detector → more possibility for 1 TeV
+ Variety remained to SiD, more redundancy

Consideration for Calibration

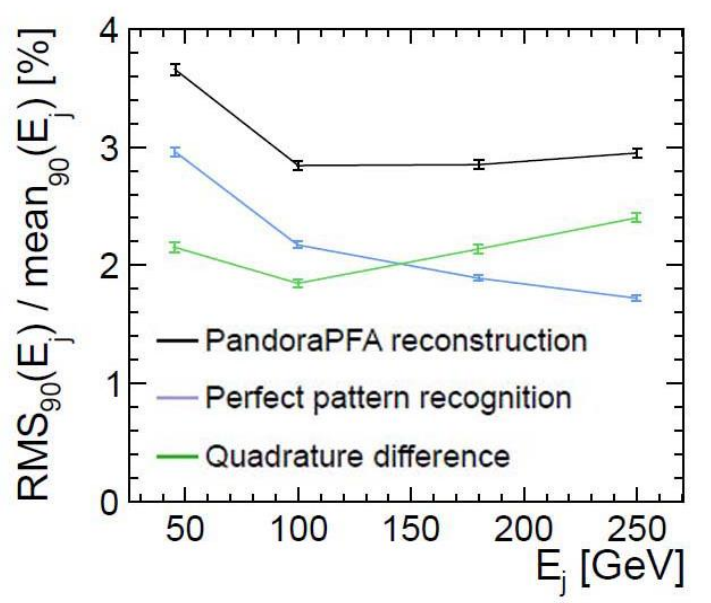
- MIP calibration
- LED calibration (Scintillator only)
  - No specific procedure for hybrid
  - Fluctuation can be seen by Si/Sc ratio
- Electron calibration
  - Compare with momentum in trackers
    - Bhabha monochromatic (125 GeV?) many stats.
    - Bhabha radiative return, WW/ZZ, continuous
  - Si/Sc ratio can be confirmed with various Es
  - Will be studied by MC
- Pion calibration – using tau (continuous only)

Optimization

What to optimize

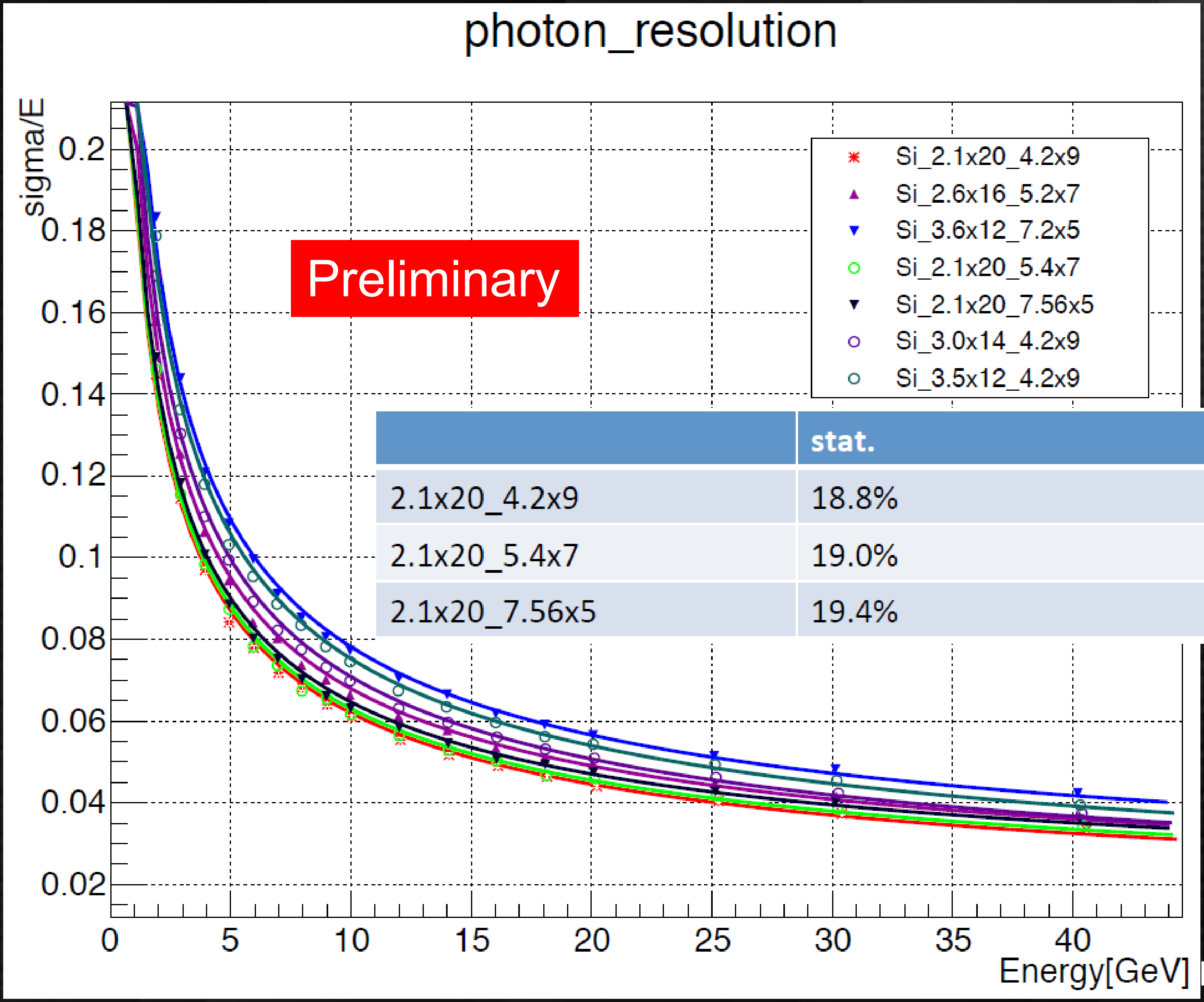
- Thickness(es) of absorber (number of layers)
- Granularity (pixel size)
- How to combine Si/Sc
  - Fraction of Si/Sc
  - Alternate or grouped

N layers & Granularity



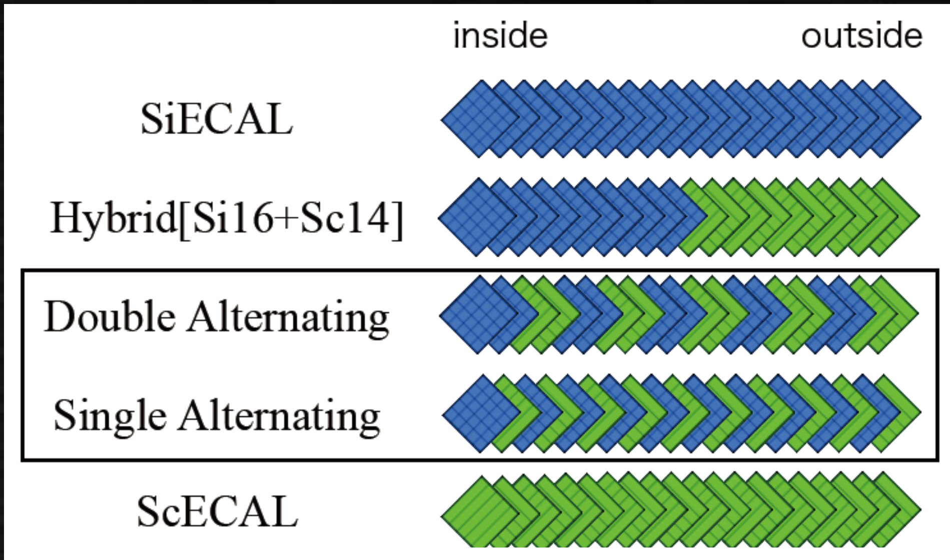
- Jet energy resolution is dominated by
  - Intrinsic resolution @ low E (Mainly HCAL)
  - Confusion @ high E
- Other physics
  - π_0 reconstruction in tau (Higgs CP etc.) → relatively high energy photons
  - H→$\gamma\gamma$ (higher energy)
  - Photon pointing (BSM study)

A study of # layers

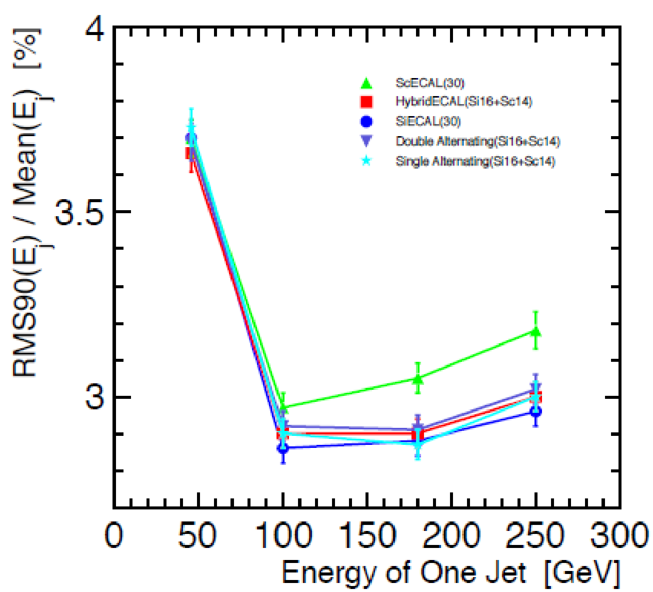


	stat.	const.
2.1x20_4.2x9	18.8%	1.47%
2.1x20_5.4x7	19.0%	1.63%
2.1x20_7.56x5	19.4%	1.79%

Hybrid: alternate or grouped?



Essentially the same performance in DBD detector
→ grouped setup is favored for simplicity
More check (tau etc.) needed



RMS90(E_j) / Mean(E_j) [%]

	45GeV	100GeV	180GeV	250GeV
SiECAL	3.70	2.86	2.88	2.96
Hybrid [Si16+Sc14]	**3.66**	**2.90**	**2.90**	**3.00**
Double	**3.69**	**2.92**	**2.91**	**3.02**
Single	**3.73**	**2.90**	**2.87**	**3.00**
ScECAL	3.70	2.97	3.05	3.18

Optimization - ToDo

- Optimization still in early stage
  → One proposal should be shown in a year
- Plans
  - Hadron energy resolution study
  - Confusion study with different granularity and combination of Si/Sc
  - Tau/π_0 separation study
  - Test of calibration procedure in MC
  - Goal: cheaper (similar to 1400 mm) detector without significant degradation of performance

DAQ

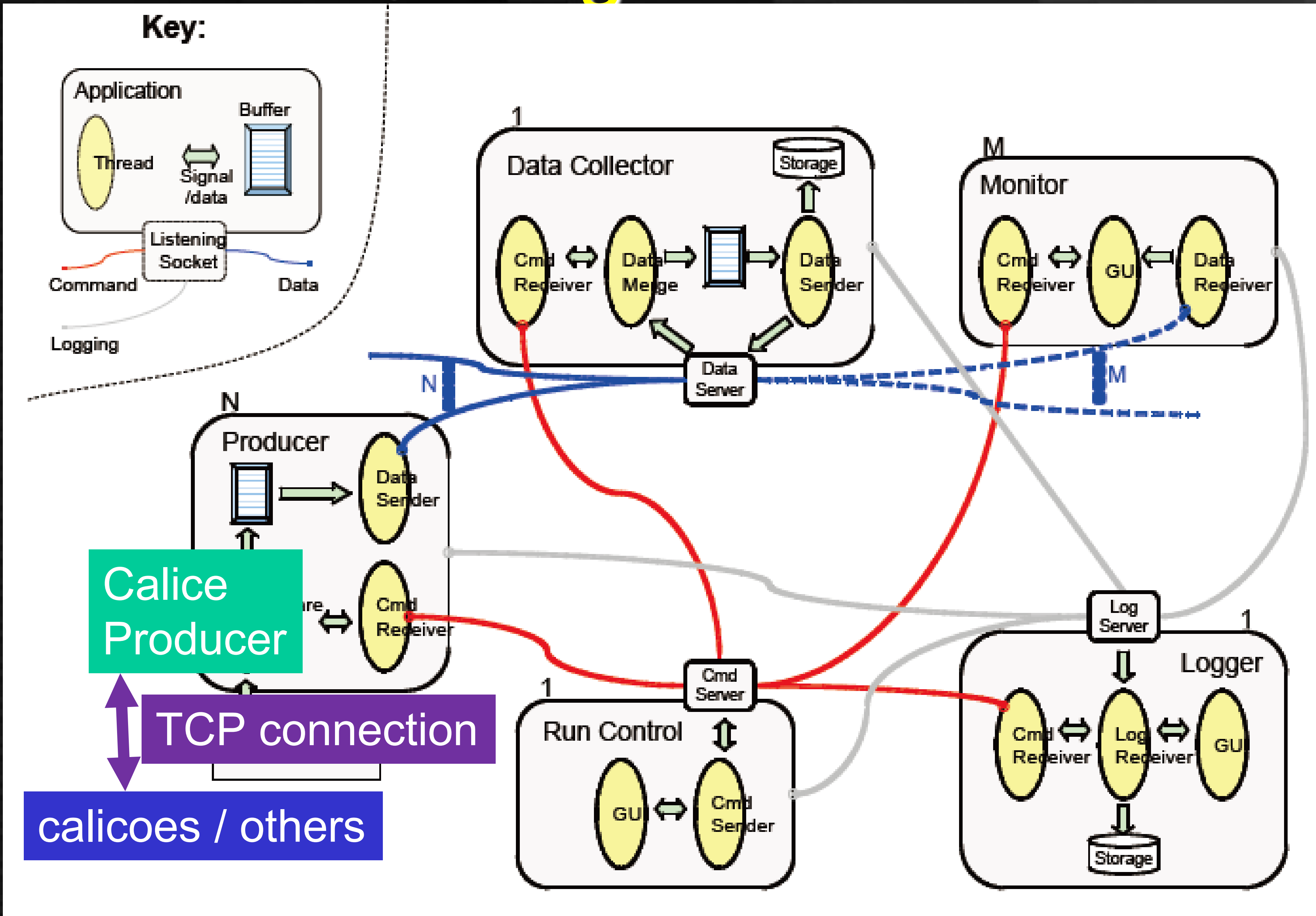
Combined DAQ - motivation

- “CALICE DAQ” was aimed to unify all efforts involving DAQ of calorimeters to save resource.
  - “ROC” chips → successful
  - DIF/LDA board → spilt some years ago
  - Software → completely independent

At some point, we should unify (again)

→ Hybrid ECAL is a good start point

EUDAQ: a high level structure



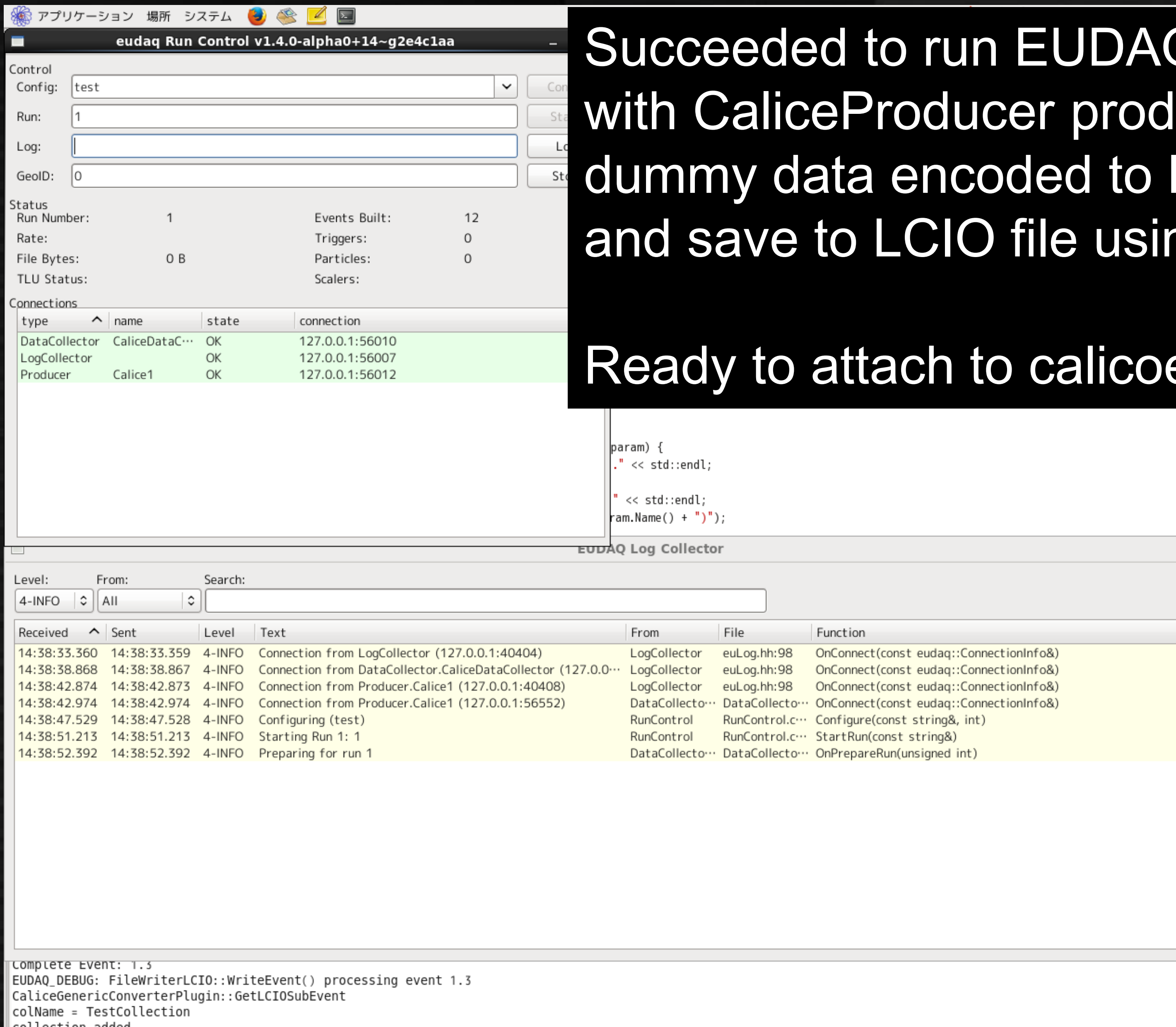
Planned test of combined DAQ

- 2nd TB period at CERN in this Autumn
  - 26th November to 8th December
  - Mainly AHCAL testbeam with 3 ScECAL layers
- We will put a Si layer in front of Sc layers
- Minimum-combined DAQ will be tested
  - Developing now
  - based on EUDAQ

Current status

Succeeded to run EUDAQ
with CaliceProducer producing
dummy data encoded to LCIO object
and save to LCIO file using DataCollector

Ready to attach to calicoes/others



Combined DAQ - ToDo

- General discussion has started at last CALICE technical board
- Agreement at all-CALICE is needed about the framework to be used (at least)
- Gradual approach is the only possibility now - if we don't have a strong group doing everything
- I hope it well proceed in several years to one "ILC DAQ"

Summary

- We think Hybrid ECAL is a strong option for cost-effective ILD
- We plan to finish a “optimized hybrid” setup in a year
- Combined DAQ is another issue
  we will try to combine Si/Sc DAQs
  as a first step to more generic DAQ