Summary on Calorimetry (no muons!) talks

Vladislav Balagura (LLR - Ecole polytechnique / CNRS / IN2P3)
on behalf of all conveners
Angel Abusleme,
Daniel Jeans,
Strahinja Lukic,
Lei Xia,
Tamaki Yoshioka

LCWS, Belgrade, 10 Oct 2014

15 talks, many thanks to all speakers!

date	time	title	presenter
Oct 7	14:00	Characteristic study of silicon sensor for ILD ECAL	S.Takada
	14:20	Scintillator-strip ECAL	S.Uozumi
	14:40	Hybrid ECAL: optimization and related developments	T.Suehara
	15:00	Recent progress in silicon-tungsten ECAL for ILD	V.Balagura
	16:00	Tracking in hadronic showers in the SDHCAL prototype using Hough Transform	A.Steen
	16:20	Status of the CALICE AHCAL technical prototype	F.Sefkow
	16:40	Optical fiber calibration system and adaptive power supply	Ja.Cvach
	17:00	Preliminary results from the test beam of a 1 meter long ADRIANO prototype for ILC	C.Gatto
Oct 8	14:00	Pion shower profiles extracted from CALICE data and Geant4 simulations	M.Chadeeva
	14:20	Analogue, Digital and Semi-Digital Energy reconstruction in the CALICE AHCAL	F.Sefkow
	14:40	Energy measurement with the SDHCAL prototype	A.Petrukhin
Oct 9	14:00	Overview of FCAL activities	O.Borysov
	14:20	FCAL Sensor Irradiation Studies at SCIPP	B.Schumm
	14:40	Electronics for FCAL detectors	A.Abusleme
	15:00	Optimisation of the BeamCal segmentation	L.Bortko

15 talks by topics

	Talks	presenter
Silicon ECAL	2.5	S.Takada S.Uozumi T.Suehara
Scintillator ECAL	1.5	
Analog (scintillator) HCAL	4	V.Balagura A.Steen
Semi-digital (RPC) HCAL	2	
FCAL	4	F.Sefkow Ja.Cvach
Dual readout (ADRIANO)	1	C.Gatto

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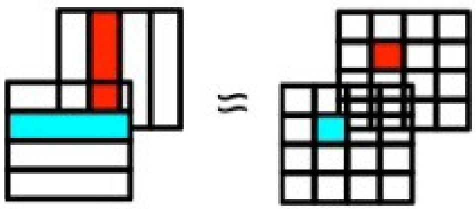
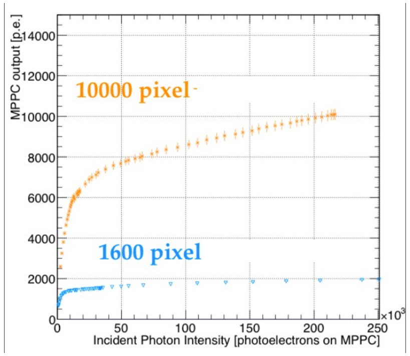
Scintillator-tungsten ECAL

S.Uozumi

5x5 mm2 virtual cells are formed by intersections of 5x45 mm2 strips in layers with alternating orientations (Strip Splitting Algorithm).
E(strip) is split in 9 E(cells) proportionally to energies in the orthogonal neighboring strips.

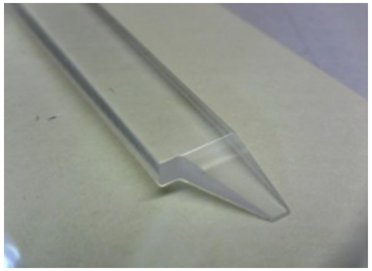


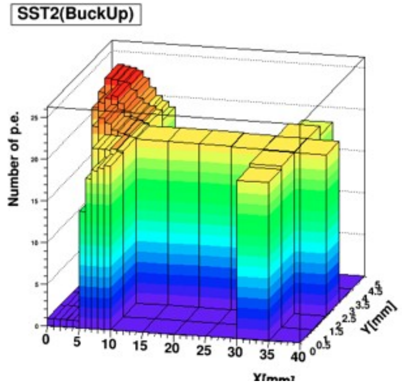
New beam test at PS has started on 8 Oct with AHCAL



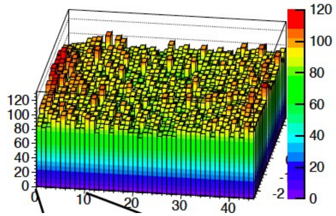
Improvements:
1. New 10,000 pixels SiPMs (10x10 um2 pixels),
X6 linearity range before SiPM saturation

2. Optimized wedge Sc shape to improve response uniformity, readout from bottom (dead zone only from reflector foil + gap)





Another idea: tapered shape with rectangular SiPM, MC non-uniformity within 7%



Silicon-tungsten ECAL

V.Balagura

Why only silicon ECAL in France? →

Why only silicon ECAL in France?

- ILC potential depends on both accelerator and detector. The latter should be considered as part of overall project. Cost savings with fully scintillator ECAL ($\sim$ 50 MILCU depending on ILD radius, cost of SiPM calibration etc.) are <1% of total ILC cost ($\sim$7-8 GILCU). Only one ILC detector is needed from physical (not political) point of view.
- Silicon advantages:
  - better granularity,
  - perfect linearity, easy calibration, time stability, robustness, → therefore, low systematics.
- No convincing argument on scintillator performance from simulation, as scintillator systematics (SiPM saturation, scintillator response non-uniformity, temperature dependence etc.) was not included in MC up to now.
- Concerning hybrid ECAL option, with both silicon and scintillator layers: complexity increases by >2, as commissioning of scintillator detectors will be more difficult than silicon. Also higher risks.
- Requirements on systematic errors in ECAL are more stringent than in HCAL. Eg. with 25% and 10% of electromagnetic and hadronic jet energy in average: $\sigma_E = 2\% \cdot 0.25E$ of ECAL systematics translates to 2% · 0.25 / 0.1 = 5% of equivalent HCAL systematics. Note: there may be more π^0 energy in jet due to large fluctuations.
- Synergy with CMS endcap Phase 2 upgrade project HGCAL also with silicon technology (alternative: shashlyk option, final choice in spring 2015).

Si producers:

- Hamamatsu HPK offered sensors from 6' wafers, 500 um thick for full ECAL for 2.5 EUR/cm2 (== DBD price, 45% of ECAL cost estimation is confirmed)
- LFoundry (Europe), 8' wafers, 700 um → 6% better photon energy resolution
- ...

DAQ electronics:

- FE chip SKIROC 2B production by end of 2014,
- new FE PCB with x4 channels (ILD channel density) + LV/clock board,
- ready for gluing 4 sensors per PCB,

- assembly of short slab with one FE PCB by end of 2014,
- long slab with many FE PCBs in 2015

Mechanical design + prototyping are well advanced and ongoing.

ILD dimensions

Simulation of ILD with reduced dimensions and N layers:
Reduce ECAL price by ≈40% (with corresponding savings on magnet yoke, coil, TPC, HCAL and muon) at the cost of ≤10% jet energy resolution degradation.

Should we buy it? 10% degradation, is it small enough?

- need a benchmarking study (see ILD optimization talk by J.List)
- 10% may be at the level of our cost/performance optimization error

Example: Pandora performance has been improved from LOI by 0.1 – 0.3% for 100 – 250 GeV jets! Excellent job!

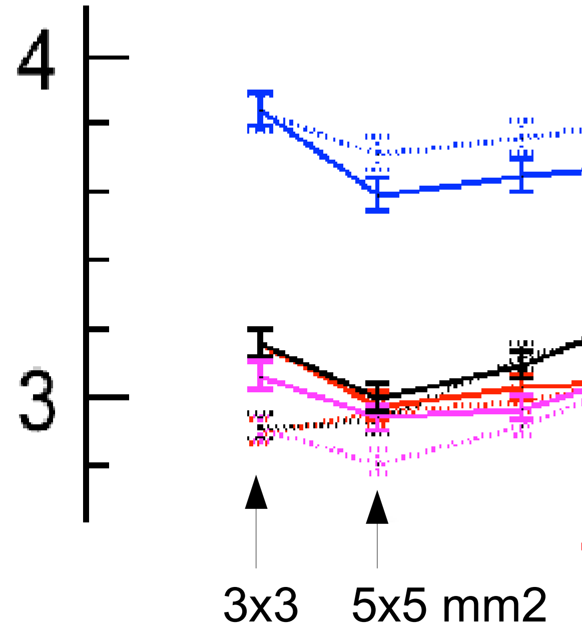
When ILC budget is approved:
tender for best PFA for 1% of savings on ILC operation costs??

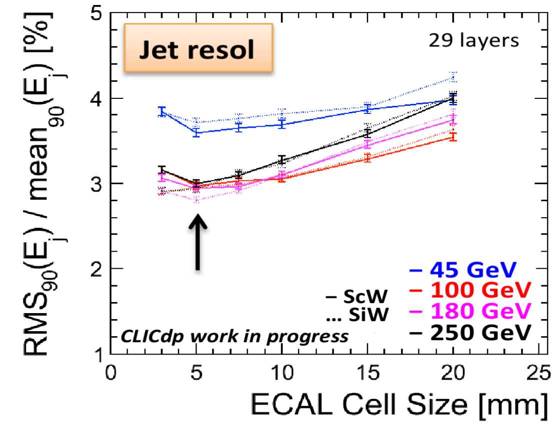
ILD dimensions vs CALO granularity

Another example:
jet energy resolution versus
ECAL granularity

Degradation at 3x3 mm2 for Silicon for all energies except 250 GeV can come only from algorithm

This may indicate a potential for improvement at 5x5 mm2 and below – to be studied?





Sc, degradation below 5mm could be due to non-sensitive area of SiPM

Si, no degradation expected below 5 mm

Current Si readout technology does not allow granularity better than ≈4x4 mm2.
One may study Si strips with the same area (and smaller virtual cells), as for scintillator, at least in 1st layers?

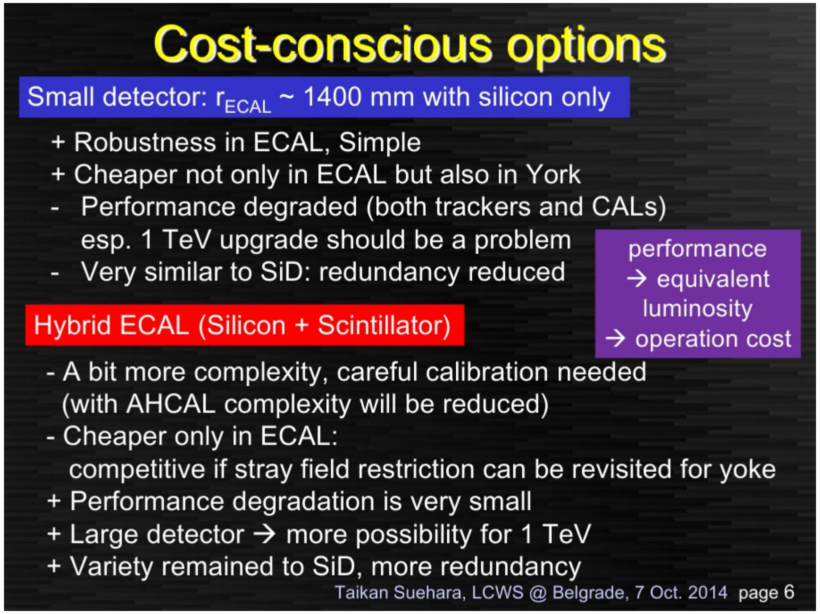
Another possibility: HCAL software compensation in Pandora.
Works in data, **may improve** energy resolution for at least very low-momentum jets?

Hybrid (Si+Sc) ECAL

T.Suehara

Arguments for Hybrid Si+Sc ECAL

Larger detector than with pure SiECAL but more complex, for the same cost



Hybrid (Si+Sc) ECAL

T.Suehara

Arguments for Hybrid Si+Sc ECAL

Larger detector than with pure SiECAL but more complex, for the same cost

Possibilities to calibrate Sc (will be studied in MC):
- MIP, - LED,
- with electrons: Bhabha, from WW/ZZ
- with pions from tau
- Sc/Si intercalibration

Optimization: photon and JER resolutions
(for ideal Sc response µ dE/dx)
Plan: optimized hybrid setup in one year

Common DAQ development: started within CALICE (common *ROC chips) but then **diverged.**

It should be re-unified again!

Hybrid ECAL DAQ may be a good starting point.
Needs a strong support from all groups!
We need to remember that there will be a common ILC DAQ in the future.

Cost-conscious options

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

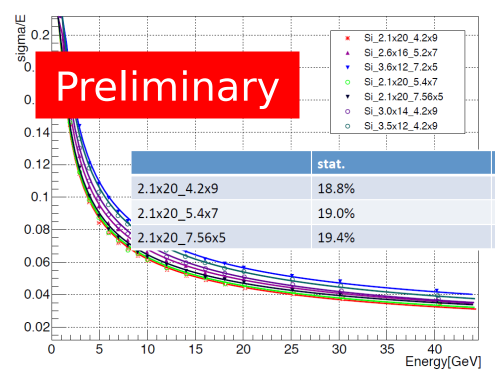
+ Robustness in ECAL, Simple
+ Cheaper not only in ECAL but also in York
- Performance degraded (both trackers and CALs)
  esp. 1 TeV upgrade should be a problem
- Very similar to SiD: redundancy reduced

performance → equivalent luminosity → operation cost

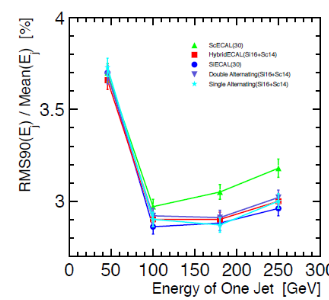
Hybrid ECAL (Silicon + Scintillator)

- 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

Taikan Suehara, LCWS @ Belgrade, 7 Oct. 2014 page 6



	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%



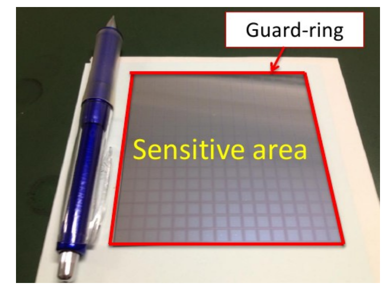
RMS90(E_j) / Mean(E_j) [%]

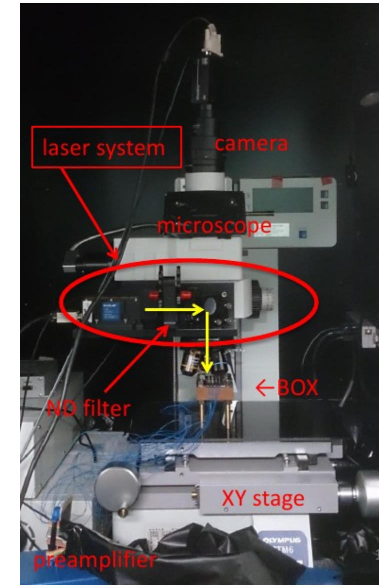
	45GeV	100GeV	180GeV	250GeV
SiECAL	3.70	2.86	2.88	2.96
Hybrid [Si16+Sc14]	**3.66**	**2.90**	**2.90**	**3.00**
Double	**3.69**	**2.92**	**2.91**	**3.02**
Single	**3.73**	**2.90**	**2.87**	**3.00**
ScECAL	3.70	2.97	3.05	3.18

Si R&D for hybrid ECAL

S.Takada

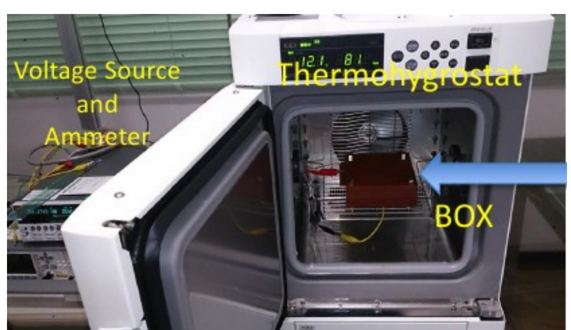
Guard ring – floating potential (to reduce cost) enables x-talk with periphery cells via capacitive coupling. With segmented GR it should be reduced. Effect is studied with infra-red laser light injected near GR.

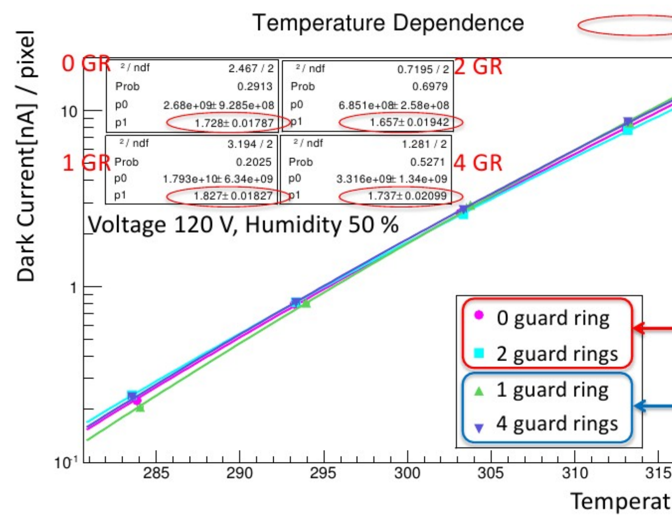




X-talk = 12% for 1 segment GR and is below 1% for 2,4 segments and for “no guard ring” design (know-how of Hamamatsu HPK).

Temperature and humidity dependence of dark currents are measured for 4 types of GR, no big differences are observed.





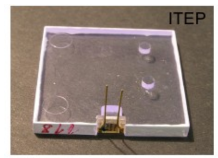
$$I(T) = AT^2 \exp(-\frac{E_g(T)}{2k_B T})$$

$$E_g(T) = E_g(0) - \frac{\alpha T^2}{\beta + T}$$

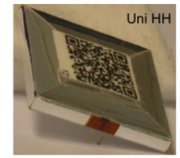
Analog HCAL

F.Sefkow

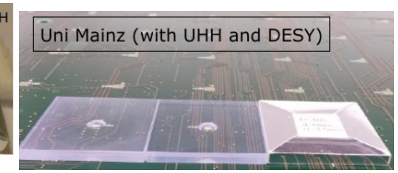
Recent SiPM progress driven by medical applications (PET): much less spread in SiPM parameters and less noise.

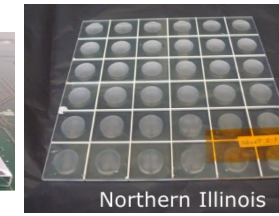


no WLS fibre
CPTA, KETEK or
Hamamatsu
sensors



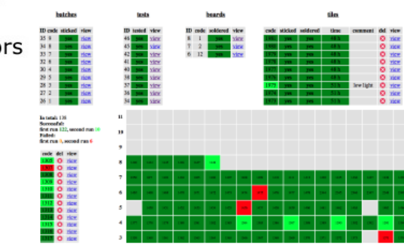
individually
wrapped;
KETEK sensors

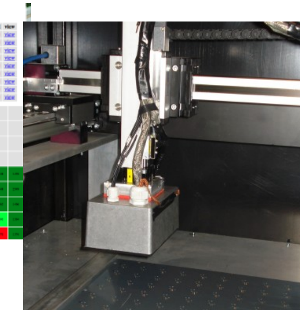


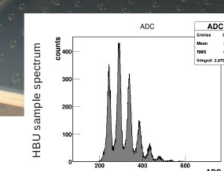


Tile options: no WLS fiber,
direct coupling – from side or top,
megatiles to simplify mass assembly

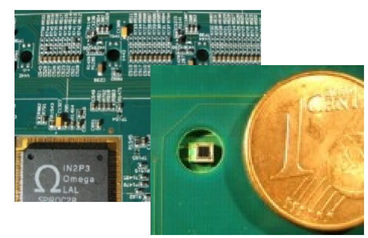
Tile characterization (Heidelberg):
- 12 ch in parallel
- 40 min / HBU



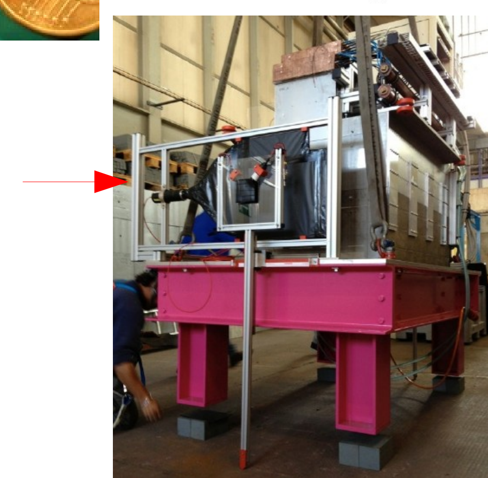




Report on LED calibration system by J.Cvach.



New AHCAL prototype:
- development of mechanics, cooling, power distribution
- FE electronics w/ surface-mounted SiPMs,
  similar for ScECAL



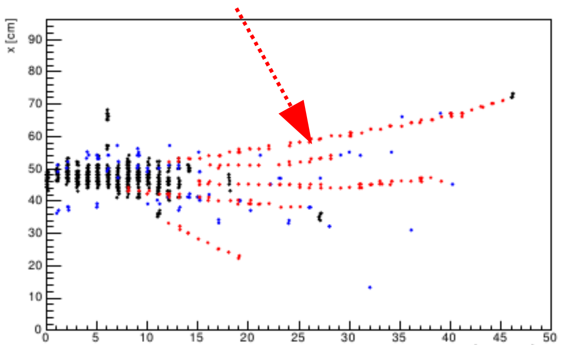
Plans:
- beam test at CERN PS started on Oct 8, second phase in Nov-Dec
- 2015-16: hadron stack w/ shower start finder, 4,000 channels
- 2017-18: hadron prototype w/ 20-40 layers, 10-20,000 channels

Semi-Digital HCAL

A.Petrukhin, A.Steen, C.Neubuser, F.Sefkow

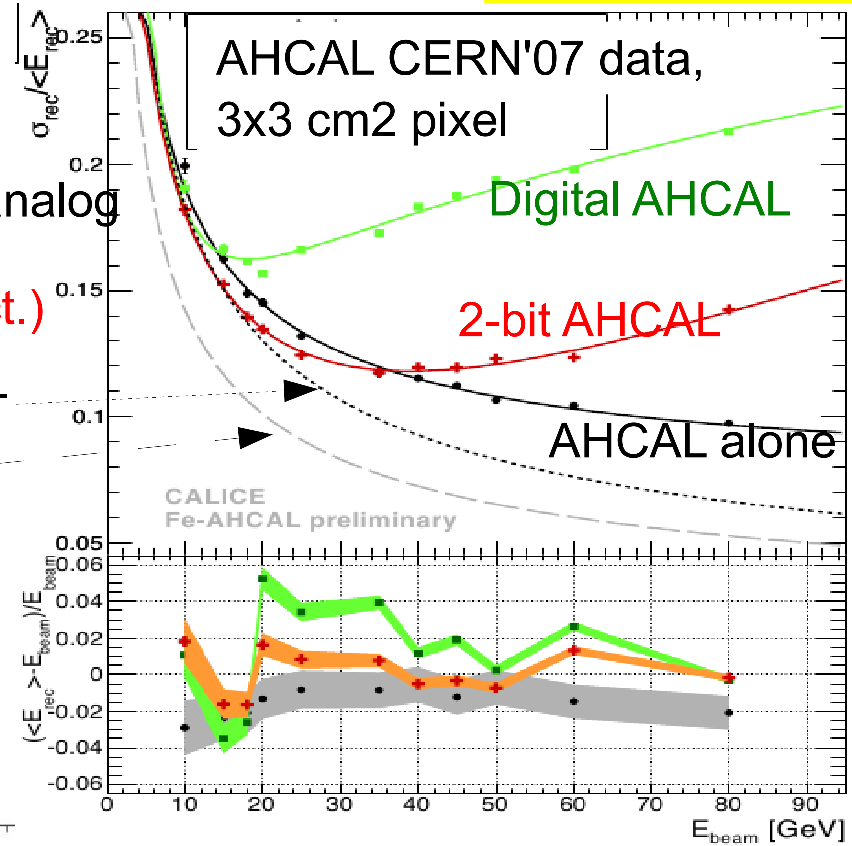
September'12 calibration is applied for November'12 data.

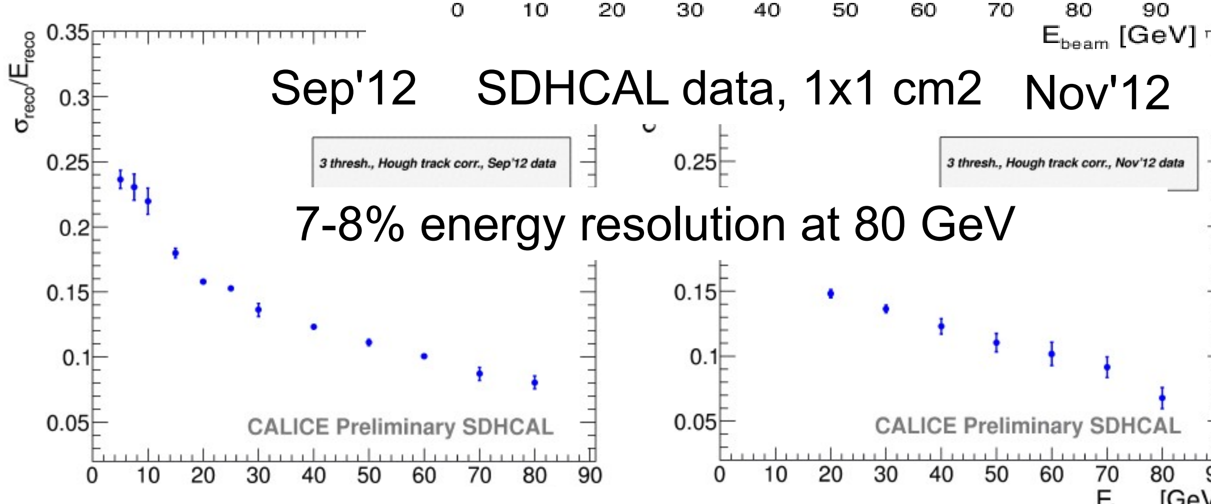
Hough Transform: robust track finding in hadron shower. Used to measure E, eff + #hits/track and verify MC models



Semi-digital < analog below 35 GeV (no Landau fluct.)

AHCAL+TCMT + Soft.Comp (best)





Non-linearity within 5%

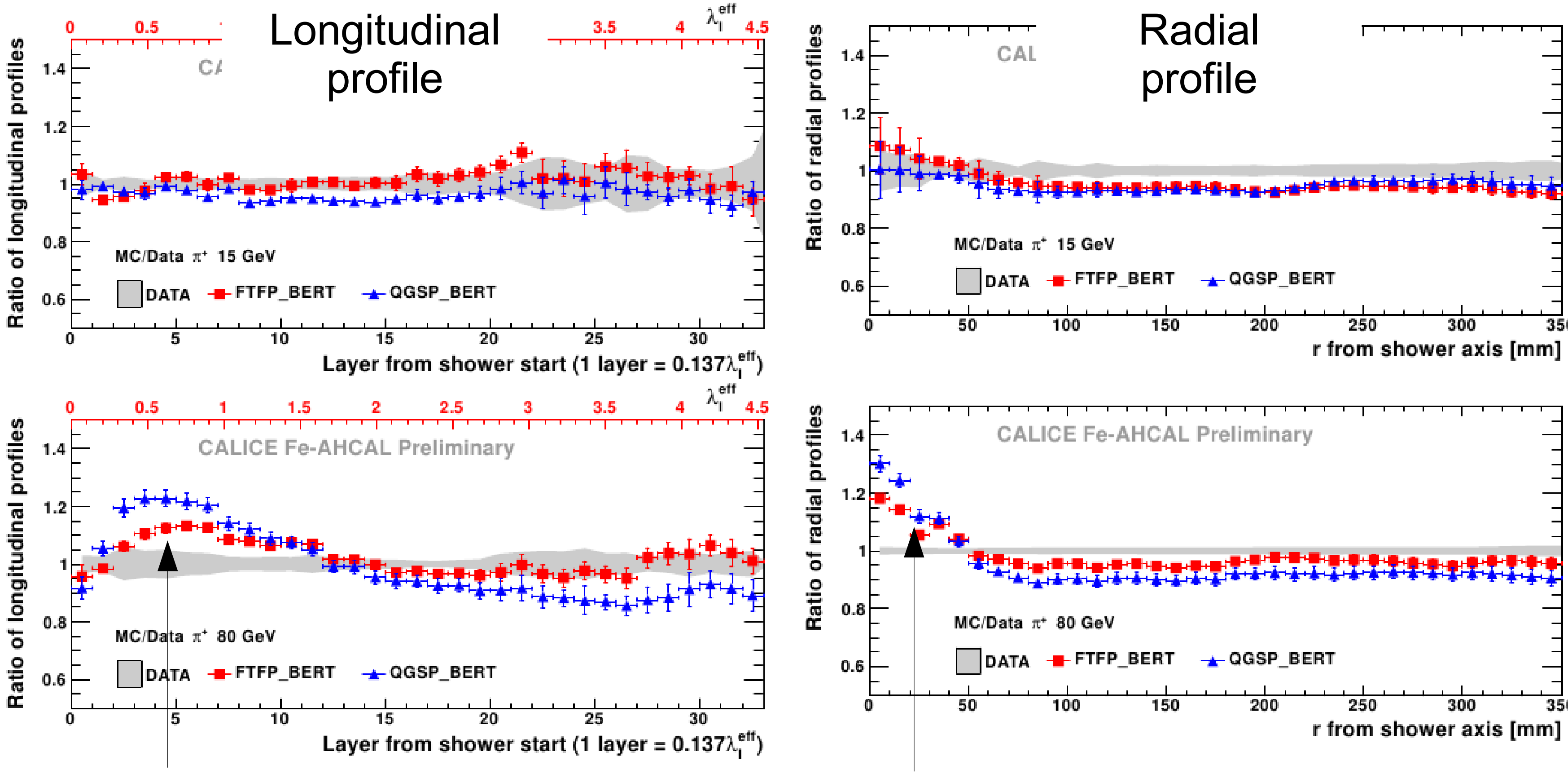
Pion shower profiles

M.Chadeeva

CERN'2007, FNAL'2009 CALICE, MC / DATA ratio:

15 GeV

80 GeV



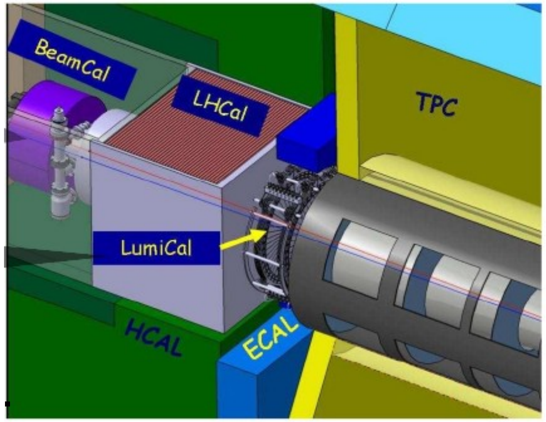
Overestimation around shower max by 10-20%!

Overestimation in shower core by 20-30%!

Double Gamma-function fit of longitudinal profile on event-by-event basis allows to estimate AHCAL leakage without tailcatcher.

FCAL overview

LumiCal (SiW) – precise luminosity measurement using Bhabha e+e-
BeamCal (?rad.hard?W) – instantaneous lumi measurement + beam monitor
FCAL improves hermeticity which may be important for physics.
Si may potentially be used in BeamCal according to T-506 irradiation studies at SLAC.

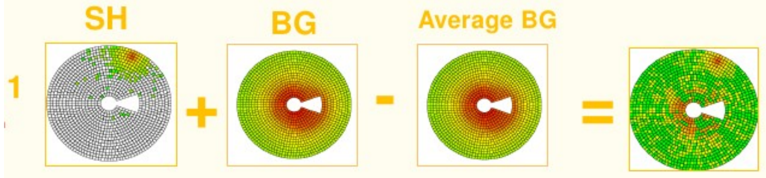


O.Borysov, B.Schumm, L.Bortko

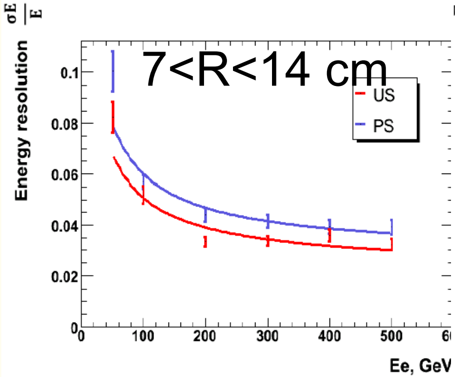
Currently, sufficient LumiCal and BeamCal precisions, but change of beam conditions due to L* and beam gas background may require redesign.

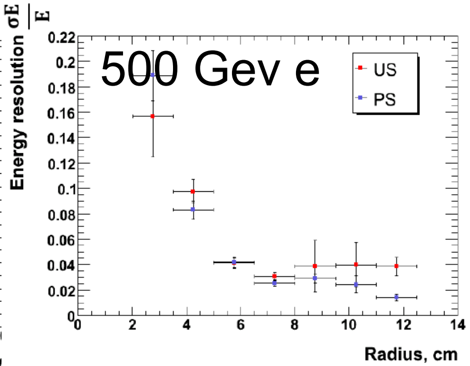
Source	Value	Uncertainty	Luminosity Uncertainty
σ_θ	2.2×10^{-2}	100%	1.6×10^{-4}
Δ_θ	3.2×10^{-3}	100%	1.6×10^{-4}
a_{res}	0.21	15%	10^{-4}
luminosity spectrum			10^{-3}
bunch sizes σ_x, σ_z,	655 nm, 300 μm	5%	1.5×10^{-3}
two photon events	2.3×10^{-3}	40%	0.9×10^{-3}
energy scale	400 MeV	100%	10^{-3}
polarisation, e^-, e^+	0.8, 0.6	0.0025	1.9×10^{-4}
total uncertainty			2.3×10^{-3}

Present GuineaPig simulation:
BeamCal is sensitive above 50 GeV. At 50 GeV the fake rate due to beamshtrahlung is 0.5% for R>7 cm, energy resolution = 10%, at 200-500 GeV – 4%.



BeamCal resolution vs E and radius

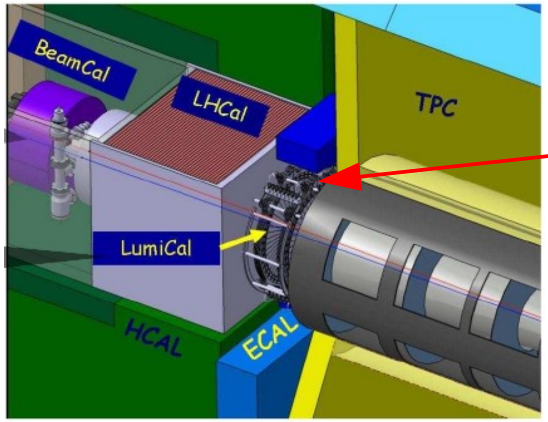


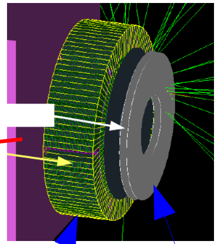


FCAL overview

O.Borysov,
A.Abusleme

Open questions:
- integration w/ ECAL,
- tracking detector in front of LumiCal may be helpful

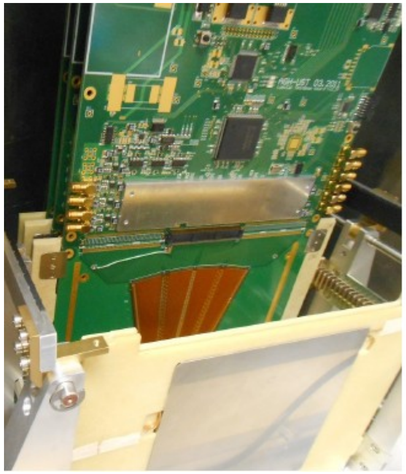




LumiCal

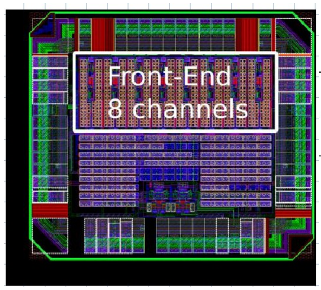
2 layers of tracking

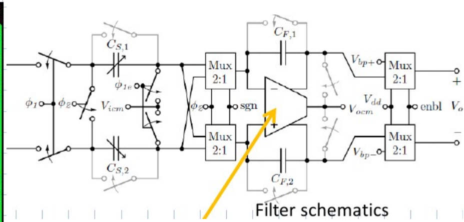
4 LumiCal layers, W plates and mechanical frame are ready for prototype beam test in Oct'14
Paper with TB'2010-12 results in final preparation.



FE chips for LumiCal (presented at TWEPP'13,14):
- 8 channels in CMOS 130 nm, C=5...50 pF,
  peak power = 1.5 mW/ch (no ADC),
  x-talk<1%, S/N>25 @MIP
- 8 ch 10-bit SAR ADC in CMOS 130 nm to be tested
- also IC in AMS 350 nm

for BeamCal:
- 3 channels in 180 nm, tested
- ADC linearity compensation, intentionally nonlinear ADC (eg. for calorimetric measurements w/ sigmaE = k sqrt(E))

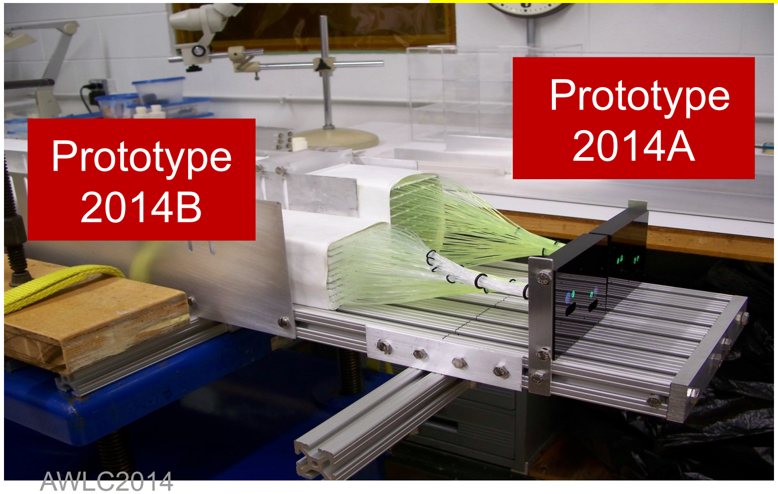




ADRIANO dual readout prototype

T1015 Collaboration, 2010 – 2015, 15 detectors built

C.Gatto



2014 prototypes:
- Cherehkov light in lead glass is collected by optically coupled WLS fibers
- Scintillating light comes from WLS fibers optically separated from glass (2014B) or from scintillator plates with WLS readout (2014a)

Difference from DREAM:
- Cherenkov and scintillator light from optically separated media,
- glass (stable, cheap, can be long, fast signals) instead of crystals

With future time measurement may distinguish neutrons after 50 nsec (triple readout).

Beam test 2 weeks ago, 2014b: 450/GeV Sc photons, 360/GeV Cherenkov ph. (goals achieved).
In MC simulation: Cherenkov yield is sufficient for 33%/sqrt(E) $\oplus$ 2%.

Still, very preliminary analysis revealed some unexpected E(electron) non-linearity and response non-uniformity in the scan along fibers.

Summary

Summary

It is impossible to make it in 13 minutes!