ILD Philosophy

1) Particle Flow **calorimetry**
   - “basic requirement”: sep of H → WW/ZZ → 4j
     - $\sigma_Z/M_Z \approx \sigma_W/M_W \approx 2.7\% \odot 2.75\sigma$ sep $\Rightarrow \sigma_E/E \text{ (jets)} < 3.8\%$
     - $60%/\sqrt{E} \rightarrow 30%/\sqrt{E} \Leftrightarrow +\sim 40\% \mathcal{L}$

2) Large TPC
   - Precision and low $X_0$ budget
   - pattern recognition

3) Precision by Silicon detectors: vertex & Calo SET
   - flavour tagging

4) Large acceptance
   - Fwd Calorimetry: lumi, veto, beam monitoring
   - Merging of LDC & GLD $\rightarrow$ ILD
     - “best dimension”
     - Optimisation studies
Geometry: dimensions at large

- Mix of LDC & GLD parameters + optimisation studies based on PandoraPFA
- Basic measuring rod
  - $\sigma_{E_j}/E_j$ ($&$ Bgd) vs
    - TPC dimensions
    - Radius Magnet (HCAL thickness)
    - B field
- Other perfs:
  - $\tau$ reconstruction
  - ...
- Done for the baseline (Si-W ECAL + Scint HCAL)
B = 3.5 T

- **HCAL**
  - Analog: Scint/Fe
  - Digital: Rpc/Fe

- **ECAL**
  - Si/W
  - Scint/W
  - Maps: Digital
Surroundings

5-module coil (5 layers)
Barrel Yoke
Endcaps
Cryostat vacuum tank
TPC

π^0 s interaction points

Points of π interaction

Radiation length and Interaction length in front of the ECAL

Adjustable support of ISS on TPC endflange
VXD supported by beam tube
Beam pipe supported by cables from support structure

Inner Support Structure (ISS)
VX
SIT
FTD
Cables/services

SET
VXD + FTD
SIT
ETD
PFA Optimisation: Calorimeter Segmentation

Starting from LDCPrime vary ECAL Si pixel size and HCAL cell size.

ECAL Conclusions:
- Ability to resolve photons in current PandoraPFA algorithm strongly dependent on transverse cell size
- Require at least as fine as 10x10 mm$^2$ to achieve 4.0 % jet E resolution
- Significant advantages in going to 5x5 mm$^2$
- For 45 GeV jets resolution dominates (confusion relatively small)

HCAL Conclusions:
- For current PandoraPFA algorithm and for Scintillator HCAL, a tile size of 3x3 cm$^2$ looks optimal
- May be different for a digital/semi-digital RPC based HCAL

Not yet complete
Calorimetry organisations

- Different central Calorimeter types envisaged
  - All in CALICE collaboration

- Common feature
  - High granularity & compact design
  - aim at embedded readout, digitisation and storage electronics
  - Inter-spill readout
  - power pulsing
  - common DAQ

- Fwd calorimetry in FCAL collaboration
ECAL structure

- **Barrel:** 5 octagonal wheels
  - $R_{\text{min}} = 1808 \text{ mm}$; $R_{\text{max}} = 2220 \text{ mm}$
  - Width = 940mm

- **End-caps:** 4 quarters
  - $\varnothing_{\text{min}} = 800 \text{ mm}$

- **Carbone / Tungsten structure**
  - filled with Si or scintillators (option MAPS/DECAL)

- **Extensive mechanical simulation & tests**
Si/W ECAL (1)

- Structure
  - 20 layers of 2.1 mm (0.6$\times_0$) W
    + 9 layers of 4.2mm (1.2$\times_0$) W
  - 5x5 mm$^2$ granularity of Si ~ 108 M cells in total
- 10x10 mm$^2$ physics prototype tested in beam
  - FLC_PHY4=3 chips with analog readout
  - Energy resolution measured in test beam ~ 16.6%/√E(GeV) ⊕ 1.1% with S/N ratio of 7.5 for a mip signal
  - CERN 2006, 2007
    FNAL 2008, 2009
- Critical points
  - power pulsing
  - Si sensors price (3000 m$^2$)
SiW ECAL results

Too many to be fair... Check R. Poeschl Talk for more details

- Square events at high E (Guard Ring X-talk)
- Excellent long term stability ($\sigma_{\text{mip}}/\text{mip} \sim 1/50$ on 2 yrs)
- Good agreement EM Sim/Data ($\leftrightarrow$ understanding of detector)
- Optimization of E reconstruction
  - Correction of dead regions
  - pixel counting & weighting
    - layer optimisation
- Data analysis on going:
  - Reconstruction of shower shapes
    - improved position & direction rec.
  - Hadrons in ECAL
    - Geant testing with Tungsten
Scint/W ECAL (1)

- **ILD Structure**
  - 24 layers of 3 mm W
    - 2 mm scintillator + 2 mm r.o.
    - $21X_0$ in total
  - 10×45 mm² scintillator strips to reduce # of ch
  - Wavelength shifter fiber and multi-pixel photon counter (MPPC) readout
  - Energy resolution $\sim 14%/\sqrt{E}(\text{GeV}) \pm 2\%$
Scint/W ECAL (2)

- Physics prototype
  - tested in summer 2009 at FNAL
    - 30 layers of 72 strips
    - 3.5mm W
  - MPPC Correction
    - temperature
    - saturation
    - Slightly Improved resolution
  - Reconstruction code

- MPPC Developments
  - Irradiation tests
    - ~OK < 60 Gy in γ, $10^8$ n/cm²
  - Stability
  - Simulations

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DECAL (MAPS) option

- **Ultimate Spatial resolution**
  - 50×50 μm² pixels
    - TERA Pixel detector
  - TPAC readout chip
    - v1 = 168x168 pixels; 79.4 mm²

- **Expected resolution (pixel counting)**
  - 13%/√E(GeV) ±1%

- **Status:**
  - successful CERN TB of 6 sensors summer 2009
  - New SPiDeR collaboration
  - Physics prototype planned for 2012

- **Critical points**
  - integration, Power consumption, services, price, ...

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Geometries for the HCALs

- **Sensor agnostic**

<table>
<thead>
<tr>
<th>DESIGN 1 (TESLA)</th>
<th>DESIGN 2 (&quot;a la Videau&quot;)</th>
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<tbody>
<tr>
<td>Better access to electronics</td>
<td>better hermiticity</td>
</tr>
<tr>
<td>Larger radius</td>
<td>mechanical rigidity</td>
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- **48 layers of 20mm SS → 5.7 $\lambda_l$ (6.6 with ECAL)**
Fixing lines

Rotation by 22.5° improves

$e_{\text{max}} = 1.69 \, \text{mm}$

$e_{\text{max}} = 0.15 \, \text{mm}$
AHCAL: Scint/Fe with SiPM

- 3×3 cm³ × 3mm scintillator tiles
  - WLS fiber readout by SiPM (studies without)
  - Energy resolution≈ 49.2%/√E(GeV)⊕2.3%

- Physics prototype
  - 38 layers Scint + 2cm SS → 5 λ_{had}
  - extensively tested with ECAL + TCMT
    - 2006 → 2008

- Critical element
  - calibration, stability
AHCAL results

Many many results...
See Angela Lucaci-Timoce talk

- Understanding of calibration
  - LED system
  - Scint + SiPM τ & saturation correction
- Good overall agreement Data/MC
  - EM response 10-50 GeV
  - HAD response
    - Test bench for Geant4
    - Shower start & profile
    - Shower spatial separation
    - Leakage corrections
- Resolution improvement by weighting technique
- Calibration from track segments
DHCAL : semi-digital gaseous

- Glass Resistive Plate Chamber (GRPC) with 1×1cm² readout pads
  - Semi-digital (2bits) readout
  - Expected raw $\sigma_{E_j}/E_j \sim$ analogue one

- Prototypes chambers
  - small (8×32 cm² and large 1m²) RPC tested
  - with embedded electronics (HARDROC1)

- R&D
  - on semi-conductive paints
    - stability & industrial painting
  - On (fast) semi-conductive glass
  - Gas distribution
    - and replacement for Isobutane
SDHCAL (2)

- Simulation
  - Digitisation: response from RPC

- Reconstruction
  - Efficiency & multiplicity
  - Energy from hits
    - $\sum W_i \times N_i$; Neural network
  - Simulated hadronic response

\[ E_{\text{rec}} = (a \times N_{S1} + b \times N_{S2} + c \times N_{S3}) \]
Forward Detectors

- **LumiCAL**
  - Si/W
  - 32 – 74 mrad
  - Luminosity measurement accuracy of $< 10^{-3}$

- **BeamCAL**
  - 5 – 40 mrad
  - Hit by e+e- pair-background caused by beam-beam interaction
  - Si, GaAs, or diamond – W sandwich

- **Pair-monitor**
  - Placed in front of BeamCAL
  - Measure beam shape from the distribution of Pair-background
  - Si pixel detector

- **LHCAL**
  - Locates after LumiCAL
  - Si/W sandwich, $4\lambda_I$
FCAL recent developments

- **BeamCal Sensor Prototyping**
  - n-type GaAs(Te,Sn)+Cr
    - made by SIPT (Tomsk)
    - OK $\leq$ 500 kGy (10 MeV e$^-$)
  - sCVD diamond (E6), 5×5×0.3 mm$^3$
    - $\leq$ 10 MGy ($^{90}$Sr)
  - Sapphire: Single crystal, 1×1 cm$^2$
    - $\sim$ 30 % of the initial charge collection eff. after 12 MGy
  - No choice done so far

- **LumiCal**
  - High resistivity n-type Si
    - 10.8×4...12 cm$^2$
      (6 Inch Wafers)
    - I(V) & C(V) meas.
      $\rightarrow$ successful
FCAL recent developments (2)

- **ASIC Development and Test**
  - BeamCal
  - LumiCal
    - 8 channel preamplifier, lab tests, matches the requirements (power consumption, noise, lin.)
    - 1 ch. 10 bit ADC, 35 MHz on test → multichannel

- **Test beams**
  - with various sensors: scheduled for 2010
  - diamond sensor tested in bunched e- beam
    - beam profile, no EMI

- **Applications as beam monitors:**
  - 4 diamond & 4 sapphire sensors for FLASH
  - CMS : BCMF1
Integration & services

- Services & cabling
  - cooling philosophy
    - Each detector should remove its own heat
    - ECAL 120 Mch $\times 25\mu$W $\Rightarrow 3$ kW
      - with 200 gain from Power Pulsing
  - DAQ
    - 1 Concentrator board per Module
      + power
      + condensators
Main critical points

- Calibration
  - Answered to IDAG: muon from beam halo, tracks in showers

- All: Power pulsing
  - SiW: cost of Si, heating → indust.
  - ScW: reconstruction → coding / manpower
  - MAPS: power & integration → physics prototype on the way
  - AHCAL: price of SiPM, operational stability with zero suppr. → indus. + TB analysis
  - DHCAL: reconstruction & operational stability → to be validated in Simulation & TB

→ Construction of complete or partial **technological prototypes**
  - embedded ASICS
    - daisy chain readout
    - cooling
    - power pulsing testing

  ▶ (Now) For ECAL, AHCAL & DHCAL

Not yet addressed: Power pulsing in B field
Si/W ECAL Tech. Proto

- 5×5 mm² technological prototype (see R. Poeschl talk @ ILD sess.)
  - 9” wafers with improved guard rings and reduced dead zone
    - R&D on GR
  - embedded on board SKYROC2 chips [64 channels; power pulsing; ADC + 8-deep pipeline on chip]
  - 1 layer of mechanical structure completed
    - other by mid-2010
  - Cooling & thermal test ongoing
  - TB scheduled for mid for 2011

- Most critical problem:
  - Si sensors prices: now per wafer 10-20€ → 2€ for ILD
    - industrialisation (scale) / partnership / competition / self production under investigation during the next 2 years

See R. Cornat talk's at CALICE meeting
EUDET design

Composite Part
with metallic inserts
(15 mm thick)

Thickness: 1 mm

1495 mm × 550 mm

Chips and bonded wires inside the PCB

Heat shield: 100+400 μm (copper)

PCB: 1200 μm

Kapton® film: 100 μm

wafer: 325 μm

FEV7 CIP at the present time

CHIP
PCB
WAFER

2850

Froatin – CALICE meeting – 17/09/2009
AHCAL tech. proto

- 1 layer funded
- Electronics integration
  - SPIROC, daisy chain, LED
- Mechanical integration & test
  - SS plates mechanical and magnetic properties, price being investigated
AHCAL techn. prototype

- Tile optimisation
  - without WLS
  - with or w/o direct coupling
  - optimise for uniformity

- Embedded LED calibration system
  - 1 blue LED / tile
  - Studies for position & $t^\circ$ behaviour
SDHCAL

- 1 m³ technological prototype planned
  - 40 layers with 20 mm SS
  - Rpc and/or MicroMegas
  - Hardroc2 (3 thresholds)

- Testbeam scheduled for 2010-11
  - Validation of semi-digital calorimetry
  - Test of CALICE DAQ2 on 400000 channels
Overview

- Lot of engineering work in the conception of the ILD calorimetry since the LOI

- Still a lot to do to get the price reduction and establish the perf.
  - industrialisation studies are starting
    - mechanics of SS
    - Si sensors for the Si-W ECAL
  - performance program well advanced
    - techn. prototypes of (AHCAL), SDHCAL, SiW ECAL
    - Physics prototype of MAPS, Scint W, FCALs
  - Many test beam in the next 2 years

- Main points addressed by IDAG have been / will be responded
  - power pulsing in B field
    - Needs special tests
      - Under investigation...

- Find a logo for ILD....
Muon system

- **ILD muon system**
  - 10 layers of 10cm Fe yoke + few layers of thick Fe yoke interleaved with muon detectors
  - Scintillator strip, resistive plate chambers (RPC), or plastic streamer tubes (PST) as the detector
  - Muon system as “tail catcher” of HCAL: still controversial