EUDET: Detector R&D Towards the International Linear Collider

- The EUDET initiative
- EUDET activities
  - Joint Research Activities
  - Networking
- Conclusions
## Detector Challenges at ILC

### Requirements for ILC
- **Impact parameter resolution**
  
  \[
  \sigma_{r_{\phi}} \approx \sigma_{r_{z}} \approx 5 \times 10^{-5} (\text{GeV}^{-1})
  \]

- **Momentum resolution**
  
  \[
  \sigma \left( \frac{1}{p_T} \right) = 5 \times 10^{-5} (\text{GeV}^{-1})
  \]

- **Jet energy resolution**
  
  \[
  \frac{\sigma_E}{E} = \frac{30\%}{\sqrt{E}}
  \]

### Compare to best performance to date
- **Need factor three better than SLD**
  
  \[
  \sigma_{r_{\phi}} \approx \sigma_{r_{z}} \approx 7.7 \times 10^{-3} (\text{GeV}^{-1})
  \]

- **Need factor 10 better than LEP**
  
  \[
  \sigma \left( \frac{1}{p_T} \right) = 5 \times 10^{-4} (\text{GeV}^{-1})
  \]

- **Needs to be better than ZEUS**
  
  \[
  \frac{\sigma_E}{E} = 55\% \sqrt{E}
  \]

- **Calorimeter granularity**
- **Pixel size**
- **Material budget, central**
- **Material budget, forward**

- Need factor ~200 better than LHC
- Need factor ~20 smaller than LHC
- Need factor ~10 less than LHC
- Need factor ~1000 less than LHC

Adapted from M. Demarteau
EUDET

EUDET is an “Integrated Infrastructure Initiative (I3)” within the EU funded “6th framework programme”

Support improvement of infrastructure for detector R&D with larger prototypes - but not the R&D itself

EUDET is not a collaboration

- Other institutes can contribute and exploit the infrastructure
- Infrastructure can be re-located

EUDET Partner Institutes

- Charles University Prague
  - IPASCR Prague
- HIP Helsinki
- LPC Clermont-Ferrand
  - LPSC Grenoble
  - LPHNE Paris
  - Ecole Polytechnique Palaiseau
  - LAL Orsay
  - IReS Strasbourg
  - CEA Saclay
- DESY
  - Bonn University
  - Freiburg University
  - Hamburg University
  - Heidelberg University
  - Mannheim University
  - MPI Munich
  - Rostock University
- Tel Aviv University
- INFIN Ferrara
  - INFN Milan
  - INFN Pavia
  - INFN Rome
- NIKHEF Amsterdam
- AGH Cracow
  - INPPAS Cracow
- CSIC Santander
- Lund University
- CERN Geneva
  - Geneva University
- Bristol University
  - UCL London

+ 27 associated institutes
The EUDET Map

- EUDET partners
- EUDET associates

Novosibirsk
Protvino
ITEP
MPHI
MSU
Obninsk
KEK (Japan)
Dalian (China)
EUDET Budget

- 21.5 million EUR total
- 7.0 million EU contribution

- Manpower
  - ≈ 57 FTE total
  - ≈ 17 FTE funded by EU

- Most of the resources for the development of the infrastructures

- Duration of 4 years
- Extension by 1 year until end 2010 to exploit infrastructures

EU approval pending
EUDET Structure

- **Network**
  - Management
  - Detector R&D Network

- **Transnational Access**
  - Access to DESY Test Beam
  - Access to Detector R&D Infrastructures

- **Joint Research Activities**
  - Test Beam Infrastructures
  - Tracking Detectors
  - Calorimeter

- *Information exchange and intensified collaboration*
  - Common simulation and analysis framework
  - Validation of simulation
  - Deep submicron radiation tolerant electronics
JRA1: PCMAG and Telescope

- **Large bore magnet:**
  - 1 Tesla, Ø≈85 cm, stand-alone He cooling, supplied by KEK
  - Infrastructure (control, fieldmapping, etc.) through EUDET
  - Magnet fully instrumented at DESY and ready for use

- **Pixel beam telescope:**
  - 6 layers of Monolithic Active Pixel Sensor (MAPS) detectors
  - DEPFET and ISIS pixel detectors for validation
  - DAQ system
  - Demonstrator telescope in use since summer 2007
JRA1: Pixel Telescope

Phase 1: “Demonstrator”
- First test facility will be available quickly for the groups developing pixels
- Use established pixel technology with analogue readout and no data reduction
- Available since summer 2007
- So far used by about 10 different users
- 50 million tracks alone in summer 2008

Phase 2: Final telescope
- Use pixel sensor with fully digital readout, integrated Correlated Double Sampling (CDS), and data sparsification
- The beam telescope will be ready early 2009

Daniel Haas, The EUDET Telescope, N58-3, this session
JRA1: Field Map of PCMAG

- Field mapping done at DESY by CERN-PH group
- Available in different forms, depending on the needed accuracy and speed
- Field map is accurate to a few Gauss, depending on region of the PCMAG
JRA2: Tracking Detectors

- Integrate the efforts of European institutions working on tracking detectors for the ILC

- **Large TPC prototype:**
  - Low mass field cage (for JRA1 magnet)
  - modular end plate system for large surface GEM & μMegas systems
  - development of prototype electronics for GEM & μMegas

- **Silicon TPC readout:**
  - Development MediPix → TimePix
  - TPC diagnostic endplate module incl. DAQ

- **Silicon tracking:**
  - large & light mechanical structure for Si strip detectors
  - cooling & alignment system prototypes
  - multiplexed deep-submicron FE electronics
Large TPC Prototype

- A large field cage and prototype readout electronics developed to optimally use the magnet test facility.
- Field cage structure which combines light weight with excellent high voltage behaviour and mechanical stiffness.
- Field shaping strips developed.
- Field shaping system should guarantee field homogeneity of better than 1% throughout the active volume of the chamber.
- Readout electronics:
  - A programmable preamplifier – shaper ASIC
  - A digitization system based on a modified ALTRO chip (ALICE)

Klaus Dehmelt, The Large TPC Prototype for an ILC Detector, N62-4
TPC Electronics

schematics TPC electronics based on ALICE electronics

Front End Card (128 CHANNELS)

- 8 CHIPS (16 CH / CHIP)
- CUSTOM IC (CMOS 0.35μm)
- CUSTOM IC (CMOS 0.25μm)
- 570132 PADS
- DETECTOR
  - L1: 6.5μs 1 KHz
  - drift region 92μs
  - kapton cable
  - anode wire
  - pad plane

- ADC
- Digital Circuit
- RAM
- CSA
- SEMI-GAUSS, SHAPER
- GAIN = 12 mV / IC
- FWHM = 190 ns
- 10 Bit
- 10 MHz
- BASELINE CORR.
- TAIL CANCELL.
- ZERO SUPPR.

RCU

Custom Backplane

(3200 CH / RCU)

power consumption < 40 mW / channel

L1: 6.5 μs
L2: < 100 μs 200 Hz

DYNAMIC = 30 MIP
S/N = 50 : 1
DYNAMIC = 30 MIP

1 MIP = 4.2 fC
570132 PADS
TPC Electronics

CHIP Availability

EUDET
- PCA16, 160 tested for 2048ch system
- ALTRO 25MHz 160 tested for 2048ch system
- ALTRO 40MHz for high time resolution

LC-TPC project
- PCA16, 772 chips arrived.
- 25MHz ALTRO, 700 available

Full system available spring 2009

Prototype layout:
Digital TPC: The “Ultimate Resolution”
Upgrade Medipix2 chip to get 3D information: timestamp enables TOT info = Timepix

Timepix has been produced with a good yield and is working -> first test beam
Timepix covered with 4\(\mu\)m of amorphous Silicon with a standard Micromegas in He/C4H10 (80/20)

Paul Colas, Electron Counting and Energy Resolution Study from X-Ray Conversion in Argon Mixtures with an InGrid-TimePix Detector, N31-5
Silicon Tracking

- enable groups to contribute to the development of long and thin Si-detector components
- providing common tools needed to test and simulate these sensors under real life conditions

- highly multiplexed, deep submicron front-end electronics
  - with low power consumption and the possibility for power cycling
  - DSM (130 nm)

- prototype of the alignment system to work out
  - alignment challenges,
  - the distortions handling
  - calibrations for the overall tracking system

*support for large sensor R&D*
**Mechanical Infrastructure**

Motorized 3-D Table

- Suitable for testing Silicon sensors, pixel and microstrips in a beam test.
- Tested device can be moved and rotated with respect to the beam line.
- Built in a modular way, so that it can arrange different types of DUT, with alignment telescopes or without.
- Remote controlled steering motors
Central tracker prototype

- Several detecting module prototypes have been assembled with sensors and electronics
- Tested at Lab test bench
- Beam test at DESY and CERN

Signal to noise ratio: Chip 1

Entries: 17452  
Mean: 2.574  
RMS: 4.882  
$\chi^2$/ndf: 132.5/105  
Width: 0.2938 ± 0.0618  
MPV: 23.4 ± 0.1  
Const: 89.48 ± 3.73  
Sigma: 3.349 ± 0.279  

FE chip (130nm) 2 HPK 6’ sensors
JRA3: Calorimeters

- **ECAL:**
  - Scalable prototype with tungsten absorbers
  - Si-sensors & readoutchips

- **HCAL:**
  - Scalable prototype
  - Multi-purpose calibration system for various light sensing devices

- **Very Forward Calorimeter:**
  - Laser-based positioning system
  - Calibration system for silicon and diamond sensors

- FE Electronics and Data Acquisition System for the calorimeters
Construction of „real“ module pursued parallel to demonstrator studies
The ECAL “EUDET module 0”
- barrel module prototype
  - 0.4t tungsten, 1.8m long
  - ~1/6 instrumented (12k ch.)
- One tower for e test beam
  - Embedded electronics
  - 1.5mm gap (PCB + wafer + ASICs)
  - Power pulsing
- Test full scale mechanics, cooling, communication

Roman Poeschl, Response of the CALICE Si-W ECAL Prototype to Electrons, N33-7
HCAL

- Realistic structure
- Integrated electronics
- Readout architecture like ECAL
- Calibration system, test stand

B. Lutz, Test beam results from the CALICE tile hadron calorimeter, N63-3
FEM calculations

FEM calculations for different geometrical configurations

Calculations for Whole Barrel

Maximum Deformation: 18.5 mm

Max. deformation: 2.9 mm
Calorimeter Electronics

- VFCAL
  - Electronics
    - Integration is key
    - Digital part next to sensitive analogue FE
    - Power pulsing, stability
- HaRDROC
  - 64 ch digital HCAL chip
  - Under test
- SKIROC
  - 36ch ECAL chip
  - At foundry (0.35 AMS)
- SPIROC
  - 36ch analogue (SiPM) HCAL chip
  - Under design
  - More versions in the pipeline

M. Reinecke, Integration Prototype of the CALICE Tile Hadron Calorimeter, N30-178
(Calorimeter) DAQ

- Scalable DAQ system
  - Commercial hardware where possible
  - Prototype for full detector and useable in test beam

  e.g. off-detector receiver: off-the-shelf
Forward Calorimeter

VFCAL

- Sensor test stands
- Irradiation test beam infrastructure
- Readout electronics
- Laser alignment system
  - μm level precision

Over short distances accuracies reached:
Displacements in the x-y plane:  ±0.5 μm
Displacements in z direction:  ±1.5 μm

S. Schuwalow, BeamCal for ILC Detectors, N63-8
Information exchange

- www.eudet.org
- Annual workshops (open to everyone)

Computing and analysis

- Grid based computer cluster
- Common software for test beams and ILC simulations
- Embedded in ILC software & simulation effort, already used

Shower simulation

- Support from Geant4 team
- Feedback of calorimeter testbeam results

Deep sub-micron rad-hard electronics

- Access through CERN contracts
EUDET software ANALYS

- ANALYS: development of a common data analysis and simulation infrastructure
- development of a software framework for simulation,
- analysis and comparison of test beam experiments
- embedded into existing GRID infrastructure

Strategy
- the test beam software effort is tightly integrated with the overall common ILC/LDC software effort!
- benefit from synergies where possible
- same for grid: integrate with common ILC grid activities

Example: integration of DEPFET analysis

M. Killenberg, A Common Software Framework for the TPC Development, N20-1
J. Furletova, The Integration of DEPFET in to the EUDET Telescope, N30-138
EUDET/LDC Software

LCIO – persistency/data model

Generator
Simulation
Mokka
geant4

Reconstruction
Marlin - framework
MarlinUtil, CED, MarlinReco,...

Analysis

Documentation:
http://ilcsoft.desy.de

Gear - geometry description
LCCD – conditions data
Transnational Access

- Imposed by EU to foster trans-European access to research infrastructure
- Take advantage of it: apply for travel money!
  - For travel to DESY test beam
  - For travel to use any of the infrastructure created within the EUDET initiative
    - Magnet, beam telescope
    - Field cage, SiTPC, Si tracker
    - Calorimeter structure, readout, test stands

- Open to any European group
  - EUDET or not
Transnational Access

- Already available:
  - DESY electron testbeam
  - demonstrator pixel telescope
- All others will be ready in 2009

www.eudet.org

EUDET provides in the framework of the Transnational Access scheme travel support for groups from the EU and countries associated to FP6 for using the following infrastructures:

**TA1:** DESY Test Beam

**TA2:** Experiments using infrastructure developed within the EUDET project

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As example... high precision beam telescope based on pixel sensors:

- The two arm high precision telescope with different geometries:
  - All the mechanics and the cooling system for the reference sensors.
  - Operating support: mainly remote but also local in some circumstances.
- The Data Acquisition system; hardware and software.
  - You can connect your device to our Trigger Logic Unit; help is provided to set up your DAQ in our system.
- The analysis and reconstruction software EUTelescope.
  - With this telescope a pointing resolution of up to better than 3µm can be achieved.

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EUDET is an "Integrated Infrastructure Initiative" within the EU funded "6th Framework Programme". The project aims at creating a coordinated European effort towards research and development for the next generation of large-scale particle detectors.

Apply for travel money through the Transnational Access and use the EUDET infrastructures.
Conclusions

- EUDET is an “Integrated Infrastructure Initiative (I3)” within the EU funded “6th framework programme”
  - an example of the high recognition of the ILC by the European Union

- Support improvement of infrastructure for detector R&D with larger prototypes

- Different Joint Research Activities (JRA)
  - encompassing all major ILC detector components
  - completion of most infrastructures early 2009

- Networking: large impact on structuring European ILC R&D efforts

- Transnational access: Infrastructure and support open to other detector R&D activities

- Future: develop EUDET towards overall detector integration and optimization
Backup Slides
**Important Links**

**www.eudet.org**
- You can apply for travel money through the **Transnational Access** and use the EUDET infrastructure

**testbeam.desy.de**
- You can apply for test beam time at DESY
**DESY Test beam**

- Bremsstrahlungs/conversion beam with $E_e$ up to 6 GeV.
- Beam momentum steered by magnet current by test beam user.
- Rates depending on beam line, energy, target material, collimator setting and operation.

<table>
<thead>
<tr>
<th>Rates</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td>3mm Cu</td>
</tr>
<tr>
<td>1 GeV</td>
<td>~2.2 kHz</td>
</tr>
<tr>
<td>2 GeV</td>
<td>~4.6 kHz</td>
</tr>
<tr>
<td>3 GeV</td>
<td>~5.2 kHz</td>
</tr>
<tr>
<td>4 GeV</td>
<td>~4.4 kHz</td>
</tr>
<tr>
<td>5 GeV</td>
<td>~2.8 kHz</td>
</tr>
<tr>
<td>6 GeV</td>
<td>~1.5 kHz</td>
</tr>
</tbody>
</table>

In practice is the maximal event rate around 2 kHz. (3 GeV, 3mm Cu convert, Collimator ca. 5mm x 5mm)
Facilities for Test Beam User

- All three testbeam lines have
  - Interlock systems
  - Magnet control
  - Patch panels with preinstalled cables
  - Gas warning systems
  - Fast internet connection (DHCP)

- You can ask for:
  - Translation stages
  - Premixed gases
  - Superconducting Magnet (1T)
  - Beam Telescopes:
    - MVD Telescope
    - EUDET Telescope

- You have to bring:
  - Your Data Acquisition incl. computers
  - Trigger scintillators

You can apply for test beam time at DESY testbeam.desy.de

Or contact: testbeam-coor@desy.de
Si TPC Readout

See electrons from an X-ray conversion one by one and count them, study their fluctuation.
Calorimeter Module

Advantages
- 3 mm side panel
- M6 screw size

Advantage
- Slim support structure

Disadvantages
- Uncertainties regarding stability
- High tolerance requirements (e.g., holes for screws, flatness of absorber, plates)

Start from TESLA design
HCAL

- Proof of principle -> reality