ILC vertex detector test beam requirements

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a user's vision on what's needed for VTX R&D progress,
very biased by our own experience

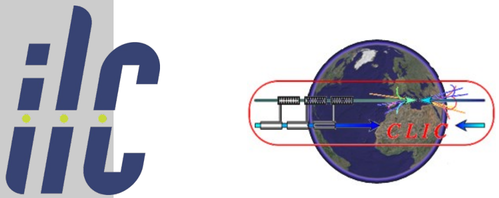
Future collider - ILC

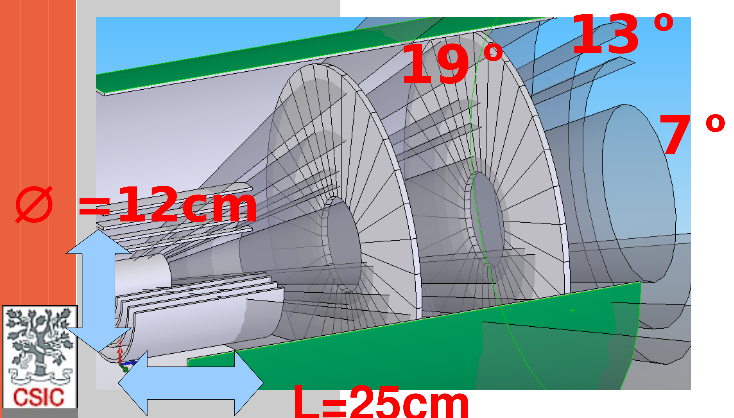
VXD: impact parameter resolution 5 – 10 μm.

This precision is required to achieve excellent heavy flavour tagging, particularly for couplings of the Higgs boson to charm (cτ ~150 μm) and bottom (cτ ~ 450 μm)

$$\sigma_{IP} = a \oplus \frac{b}{p \sin^{3/2}\theta}$$

	a (μm)	b (μm GeV)
LEP	25	70
SLD	8	33
LHC	12	70
ILC	5	10

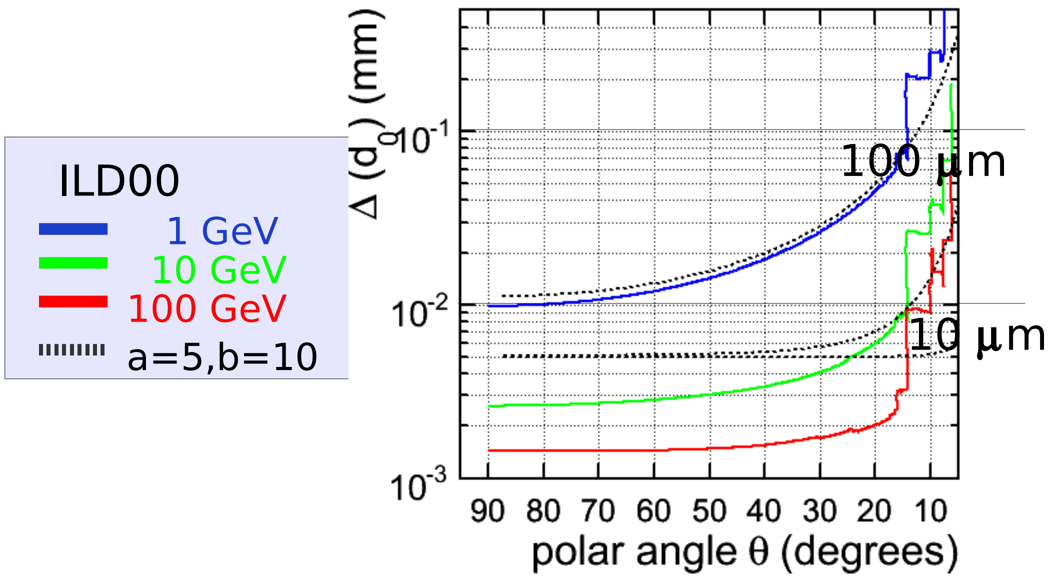




ILD00 vertex detector

Unprecedented precision
(small pixels, 20x20 μm²)

Strongly reduce the multiple Coulomb scattering term
(material: 0.1 % X_0 / layer ~ 100 μm S



VTX options

A large variety of options:

CCD – FPCCD, CPCCD, ISIS

MAPs (3T, DNW)

DEPFET

CronoPix

Vertically Integrated (VIP)

Complemented by ILC tracker R&D:

Micro-strip detectors (SiLC, SiD)

And by LHC and sLHC R&D:

Hybrid Pixels (ATLAS, CMS, ALICE, LHCb)

3D sensors

A lot of TB

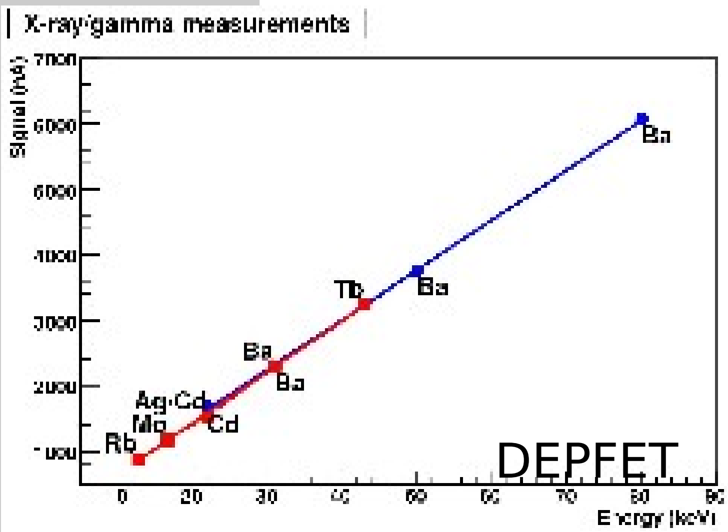
Test beam periods for R&D on silicon tracking & vertexing during summer 2009 in the CERN SPS North Area (includes LHC upgrade work)

May 18 – june 3:	*3DSi*
May 25 – May 31:	*MonoPix*
June 7 – June 20:	*SiTRD*
June 18 – June 25:	*RD42*
June 20 – June 26:	*ATLAS - gossip*
June 25 – July 1st:	*ATLAS diamond*
June 29 – July 13:	*CMS Si-Upgrade*
July 23 – 5 August:	*EUDET*
August 5 – August 12:	*DEPFET*
Augst 12 – August 19:	*LCFI*
August 19 – August 30:	*SiLC*
September 7 – Sep 13:	*ATLAS diamond*
September 14 - :	*MediPix*
September 24 – Oct 1st:	*RD42*
October 22 – Nov. 4:	*ATLAS 3DSi*
November 4 – Nov. 12:	*MonoPix*

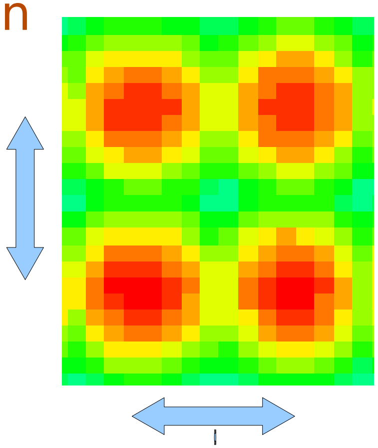
Further beam tests at DESY, FNAL,

Test beam: do we really need them?

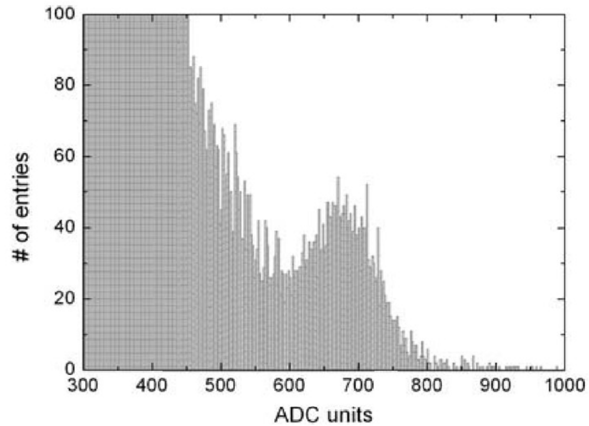
characterization using infra-red laser and gamma-sources in laboratory yields very valuable information



Absolute calibration using (fully absorbed) X- and gamma rays



Fine-focus infra-red laser to study charge collection. “seed” pixel signal vs. position, DEPFET

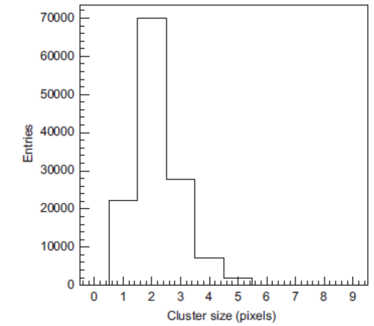


Fe55 peak in seed pixel signal. CMOS MAPs, IEEE Trans. Nucl. Sc. Vol 54 No 1.

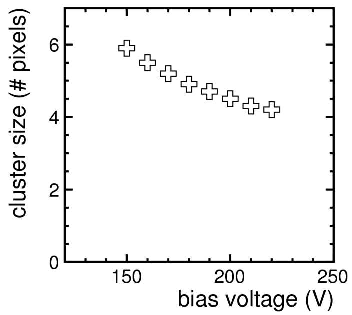
TB is useful for measurement of response to MIPs, spatial resolution, time structure, two-track resolution, Lorentz angle, ...
Also: don't forget psychology, collaboration building, etc.

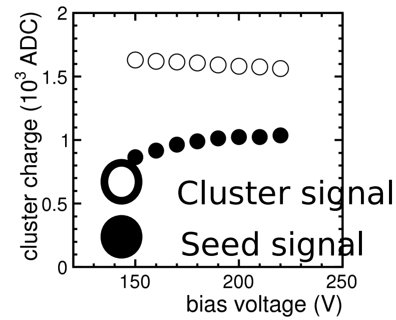
TB results – a more or less random sample

First results of the ISIS1 beam test.
J.J. Velthuis et al. 2009. 6pp.
Published in Nucl.Instrum.Meth.A599:161-166,2009.



C. Mariñas for the DEPFET collaboration, The ILC DEPFET Prototype: Report of the Test Beam at CERN, proceedings of International Linear Collider Workshop (LCWS08 and ILC08), e-Print: arXiv:0901.4639 [physics.ins-det]



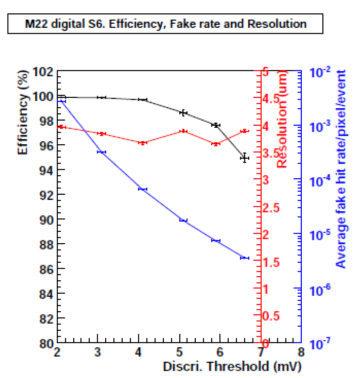


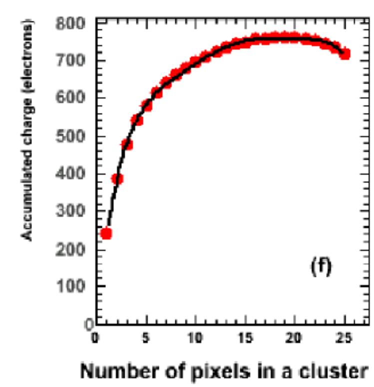
M. Winter et al., M.i.p. detection performances of a 100 us read-out CMOS pixel sensor with digitised outputs, proceedings of International Linear Collider Workshop (LCWS08 and ILC08),

e-Print: arXiv:0902.2717 [physics.ins-det]

Wojciech Dulinski et al, Optimization of tracking performance of CMOS Monolithic Active Pixel Sensors,

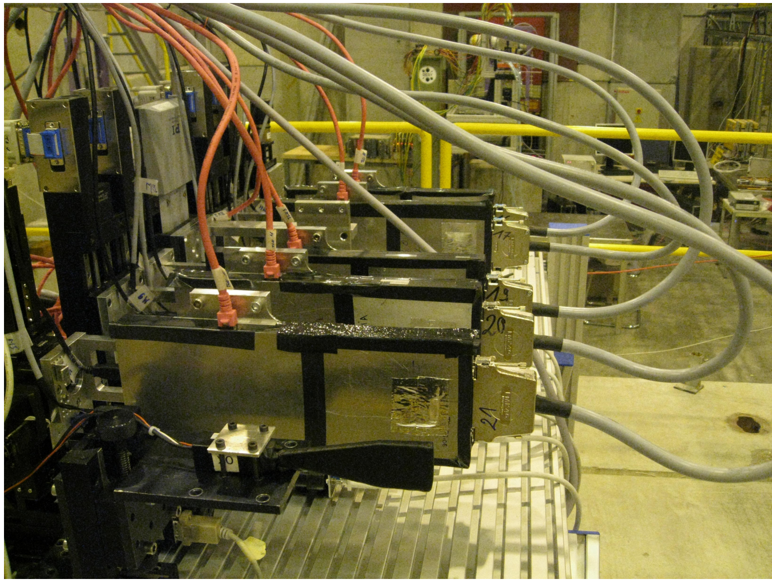
IEEE Trans.Nucl.Sci.54:284-289,2007.





EUDET or Bring-Your-Own?

EUDET: Detector R&D towards the International Linear Collider, http://www.eudet.org/.



DEPFET telescope 2009

resolution

The ILC Vertex Detector prototypes are the most precise devices around (meeting one specification is relatively easy)

Telescope with pointing precision ~ DUT resolution

Non-negligible multiple scattering (even at 100 GeV)

EUDET telescope is based on CMOS MAPs. Different generations of the MIMOSA family provide spatial resolution in the range 1-3 μm.

Generation	Pixel size	read-out	Spatial resolution
MIMOTEL	30 μm	analog	2.7 μm
MIMOSA18	10 μm	analog	0.9 μm
MIMOSA16	25 μm	binary	4.6 μm
MIMOSA22	18.4 μm	analog	< 1.5 μm
MIMOSA26	18.4 μm	binary	~ 3.5 μm

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Residuals → resolution

measurement	Residual	telescope	Multiple scattering	Resolution
X	2.0 μm	1.2 μm	0.9 μm	1.3 μm
Y	1.8 μm	0.7 μm	0.9 μm	1.2 μm

DEPFET TB @ CERN SPS 2008. 120 GeV pions, perpendicular incidence,
450 μm thick sensors. 4 X 33x24 μm^2 telescope + 24x24 μm^2 DUT
DUT resolution measurement obtained by plugging in a theoretical expectation for the Multiple Coulomb scattering (P. Kvasnicka). Energy scan used to x-check disentangling

Situation will improve once we build final demonstrators that meet all specifications (read-out speed, sensor thickness). These will have less spatial resolution. The most aggressive aim (ILD) is for 2.8 μm. Can use existing telescopes (pointing precision << DUT resolution)

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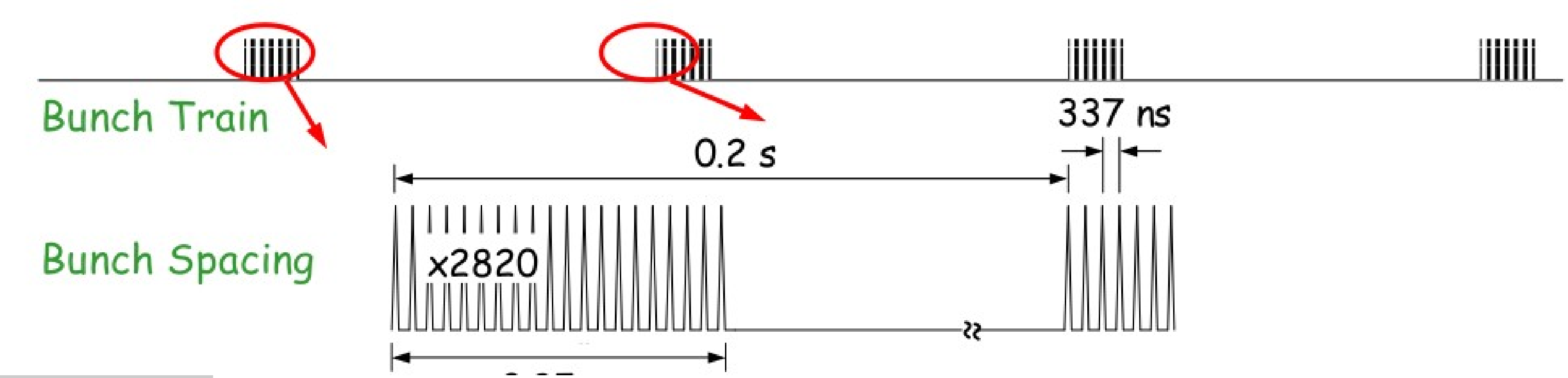
Requirements for future TB I, continuity

Several colleagues have stated that they “simply” want to continue the traditional test beam programme: EUDET telescope in high-energy beams

Requirements II, bunch structure



Needed to test pulsed-power/read-out scenarios

•A well-established request (see, for example Ingrid Gregor, LCWS08), but never done

Can we find a (cheap) work-around?

- In-time particles can be identified using a TDC measuring the trigger phase wrt ILC clock (at a large loss in statistics)
- Bunch-trains could be mimicked fairly easily in a continuous beam by some simple trigger logic

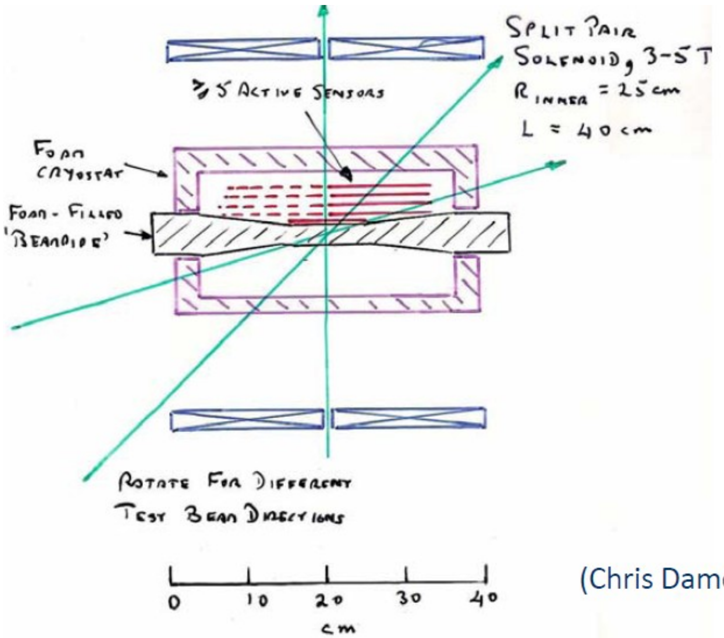
Requirements III, B-field

Needed to understand the effect on the spatial resolution (Lorentz angle)

Needed to measure standalone tracking performance

A 1.25 Tesla magnet (PCMAG) has been installed in DESY and is used by the LCTPC community

VXD community needs higher field, but can live with smaller bore

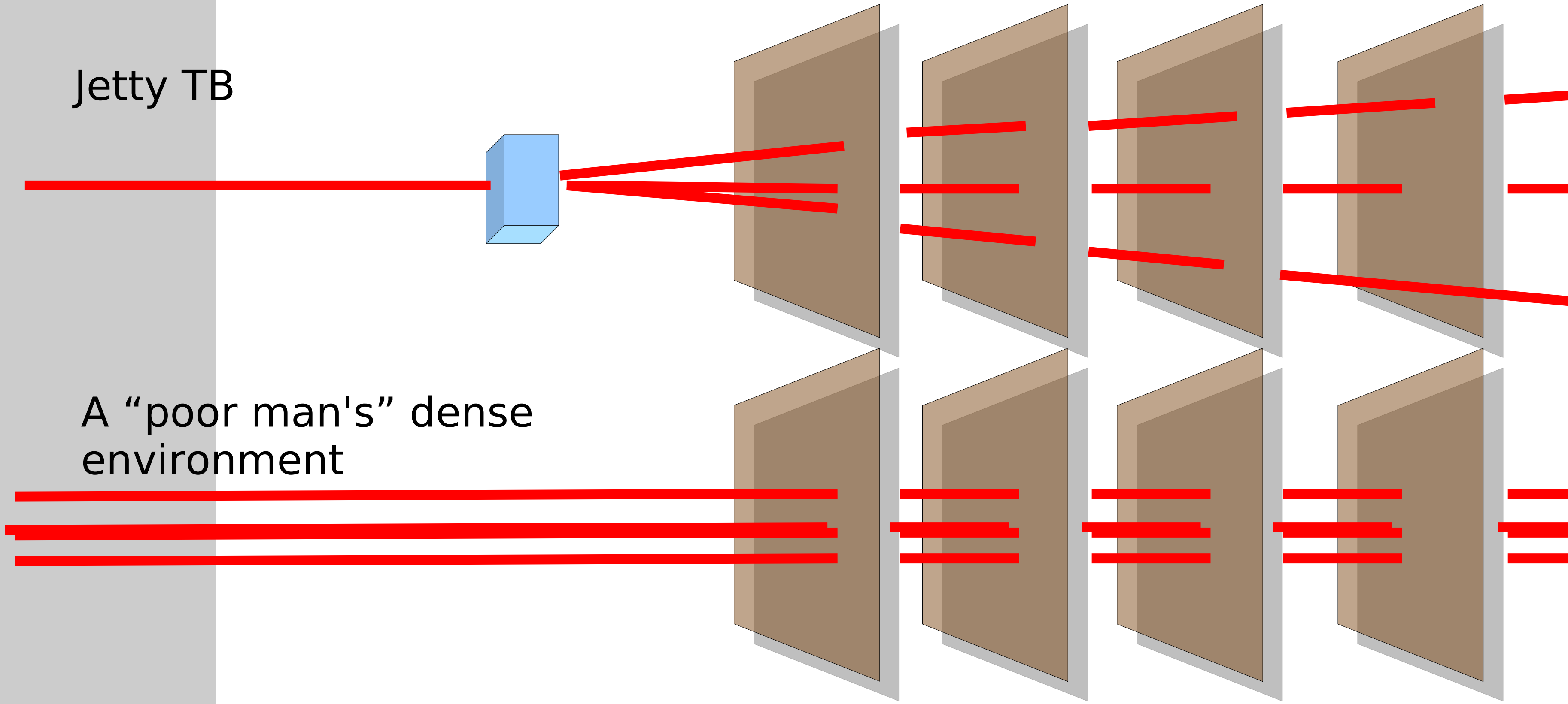


(Chris Damerell)

Requirements IV, dense environment

Jetty TB

A “poor man's” dense environment



Dense environment to study two-track resolution

(cfg. Ingrid Gregor's proposal for jet beam tests in LCWS08)

First attempts using slow read-out and intense beam have been made. Results to be analysed.

Requirements V, small area trigger

Prototypes often cover a very small area (first version of the SiTra read-out chip had 4 channels, I tried to see a signal on few 100 μm^2 APDs once).
Typical trigger scintillators in use today are too large. The alignment of such very small areas in the beam is highly non-trivial.
A trigger setup for such prototypes, where a very small scintillator (or silicon trigger device) is pre-aligned with the device under test, could be very useful in such cases.

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Requirements VI, Combined TB

Useful combinations can be (and some indeed have been) made:

- Silicon-TPC (DESY, EUDET MEMO 2007-28)
  SiLC/HEPHY Viena
- Silicon-alignment system
  SiLC/IFCA
- Full VTX-tracker slice (in magnetic field)
- VTX-Tracker-Calorimeter (Particle Flow TB)

Requires common DAQ (at some level). EUDET?
Requires significant coordination...

For comparison: the beam tests of silicon-based devices for the LHC experiments was essentially at the sub-detector level. Significant combined TB effort did not occur in ATLAS until 2004. CMS even "waited" for the magnet test. But then again, the ILC detector concepts rely much more on the integration of subdetectors.

M. Costa, W. Liebig, Test of the ATLAS inner detector reconstruction software using combined test beam data, Interlaken 2004, Computing in high energy physics and nuclear physics, 395-398

W. Adam et al. (the CMS tracker), The CMS tracker operation and performance at the Magnet Test and Cosmic Challenge, JINST 3:P07006,2008.

A. Calderón, Motions of CMS Detector structures due to the magnetic field forces as observed by the Link Alignment System during the Test of the 4 Tesla Magnet Solenoid, CMS-NOTE-2009-004

Requirements VI: software & MC

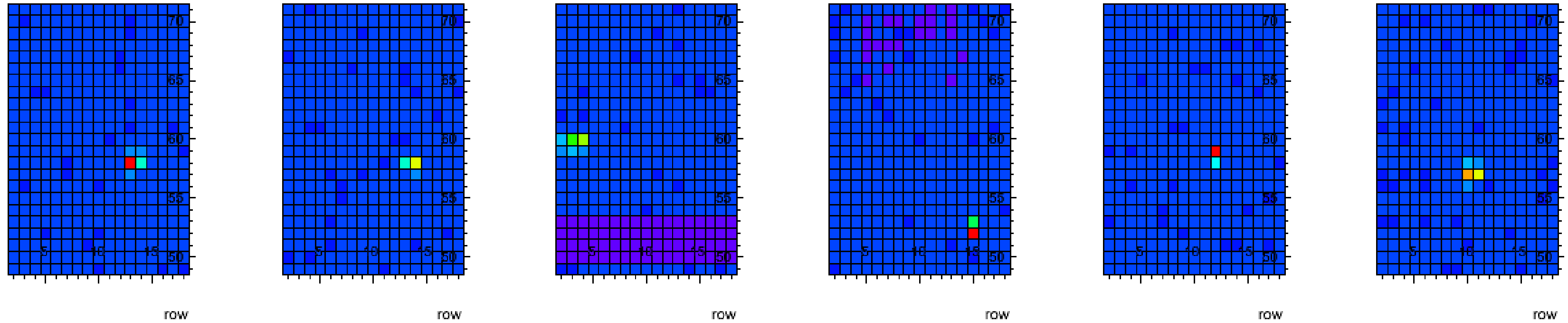
Integration in EUDET DAQ has worked for many users (to different levels)

EUDET has provided "Eutelescope" an extensive suite of analysis software within the ILC software framework
- standard data format (LCIO)
- core functionality (Marlin)
- processors for all standard analysis steps
  - Pedestal/noise calculation
  - Clustering
  - Alignment (MilliPede II)
  - Track fit
  - Analysis of residuals

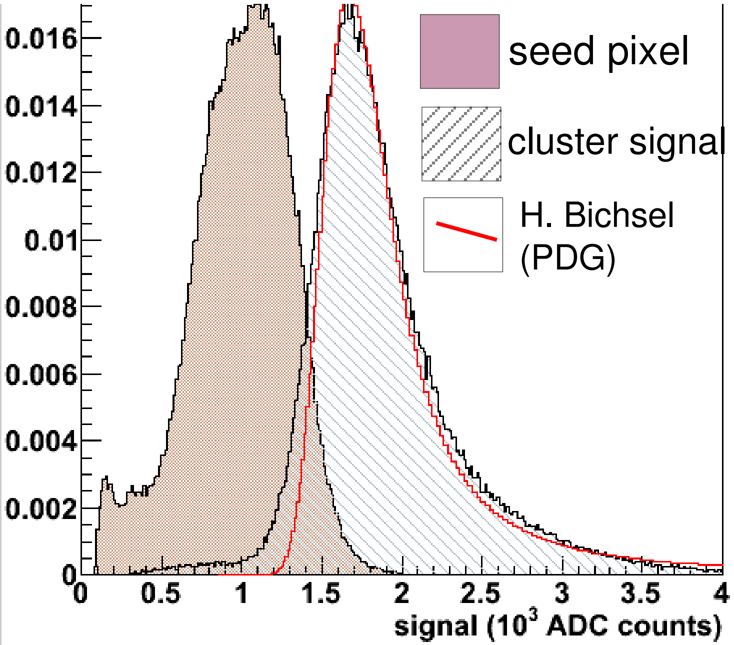
Users only need to provide some code to decode their proprietary raw data format + some software to analyse the results

Comparison with MC (i.e. Mokka GEANT4, digitizer) is in principle straightforward

Silicon detectors are well-understood?



A perfectly understable signal distribution
DEPFET TB2008, 120 GeV pions @ H6
Perpendicular incidence, 24 x 24 μm^2 DUT.

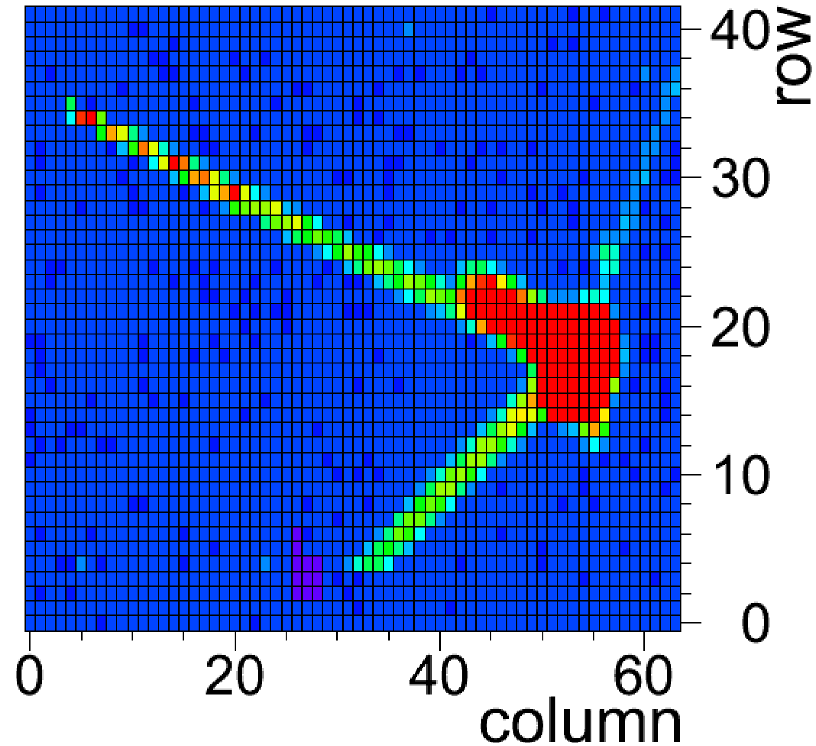


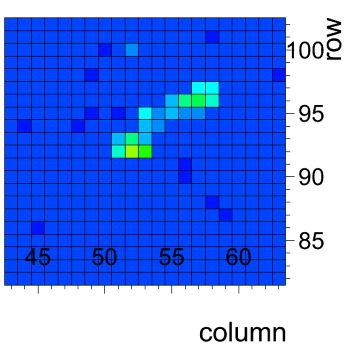
Nice, narrow clusters,
well aligned among the 6 modules

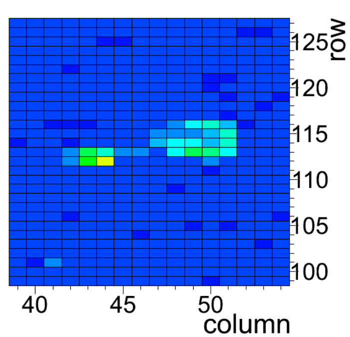
Some fun clusters

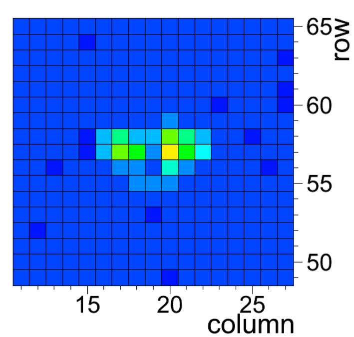
Our detectors have unprecedented performance: very fine granularity and great signal-to-noise

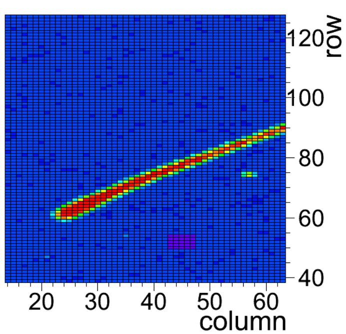
A great opportunity to understand some of the things that go on in these thin slices of silicon!











Conclusion

Plenty to learn from Test Beams
Apart from the required continuity of the standard package
– a single collaboration in a precise telescope in a high energy beam –
additional resources
– magnets, time structure, software, combined, jet-like or particle flow TB -
would enhance our understanding

Some of these resources in Europe are to be covered by the AIDA proposal (successor to DEVDET and EUDET)
Please, send your suggestions to the Work Package managers know
(these include well-known names as Ties Behnke, Ingrid Gregor, Henri Videau, M.V.)