Timepix Telescope

A new high resolution, time tagging telescope

RD50 collaboration 18th November 2010

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Outline

Timepix Chip

Medipix2 and Timepix

Timpeix Modes

Timepix Telescope

Evolution

High Resolution

Timing System – 40MHz compatiblity

Readout System and Data Rate

Cooling system

Results

Resolution

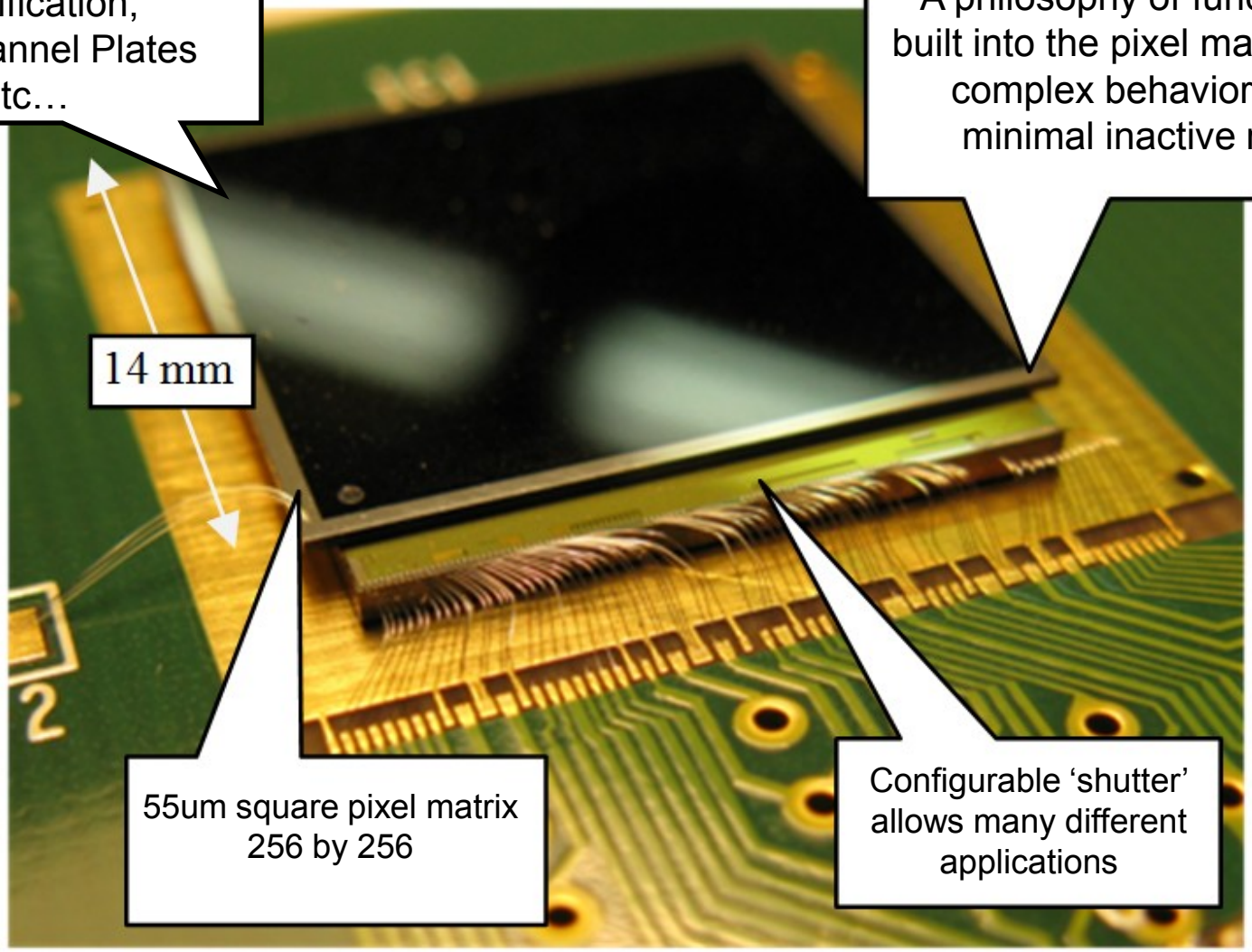
Efficiency

Sub Pixel Scans

The Medipix Chips

Silicon, 3D, CdTe, GaAs, Amorphous Silicon, Gas Amplification, Microchannel Plates etc…

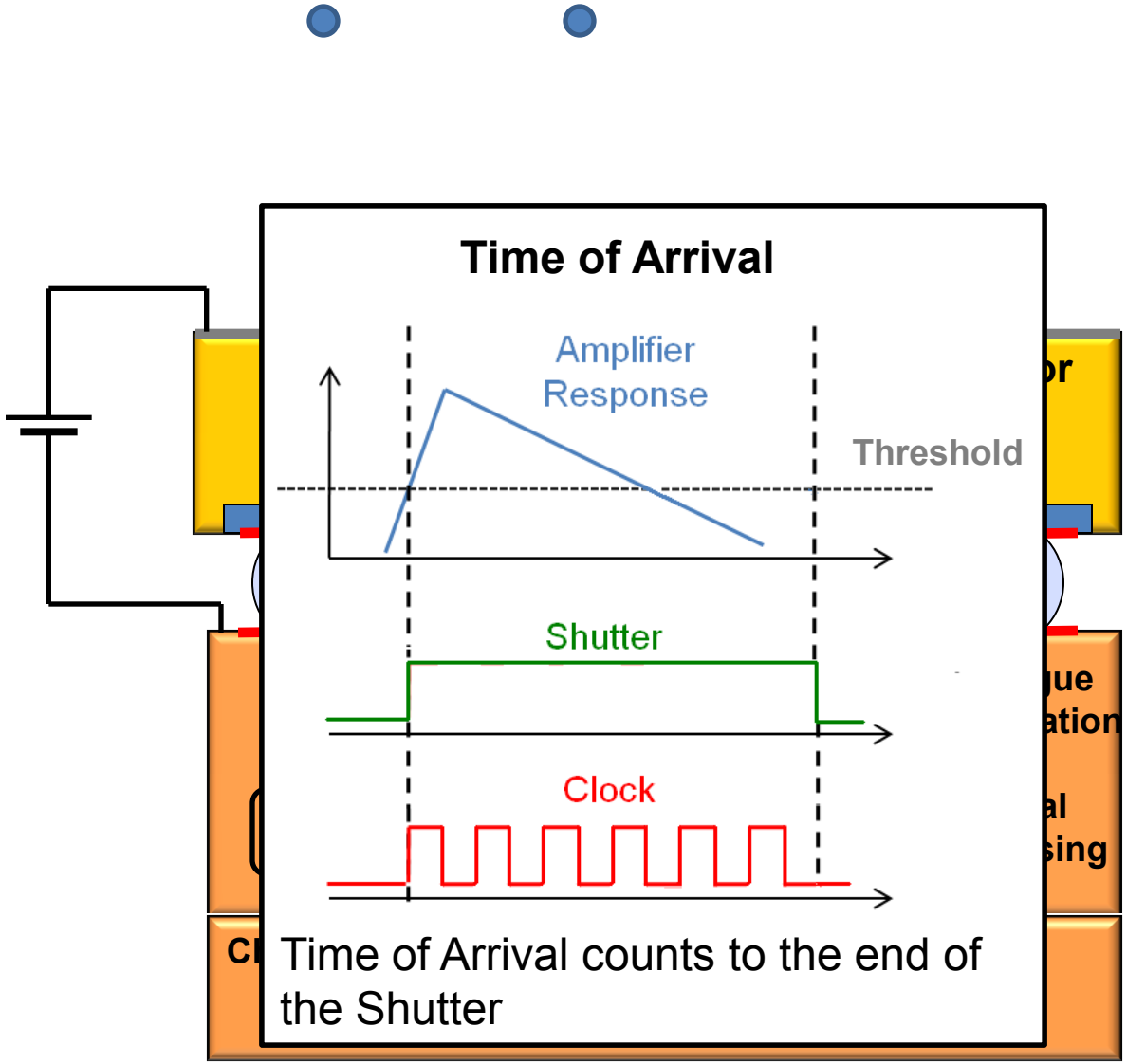
A philosophy of functionality built into the pixel matrix allows complex behavior with a minimal inactive region



55um square pixel matrix 256 by 256

Configurable ‘shutter’ allows many different applications

Timepix (2006)



Timepix design requestedand funded by EUDET collaboration

Conventional Medipix2 counting mode remains.

Addition of a clock up to 100MHz allows two new modes.

Time over Threshold

Time of Arrival

Pixels can be individually programmed into one of these three modes

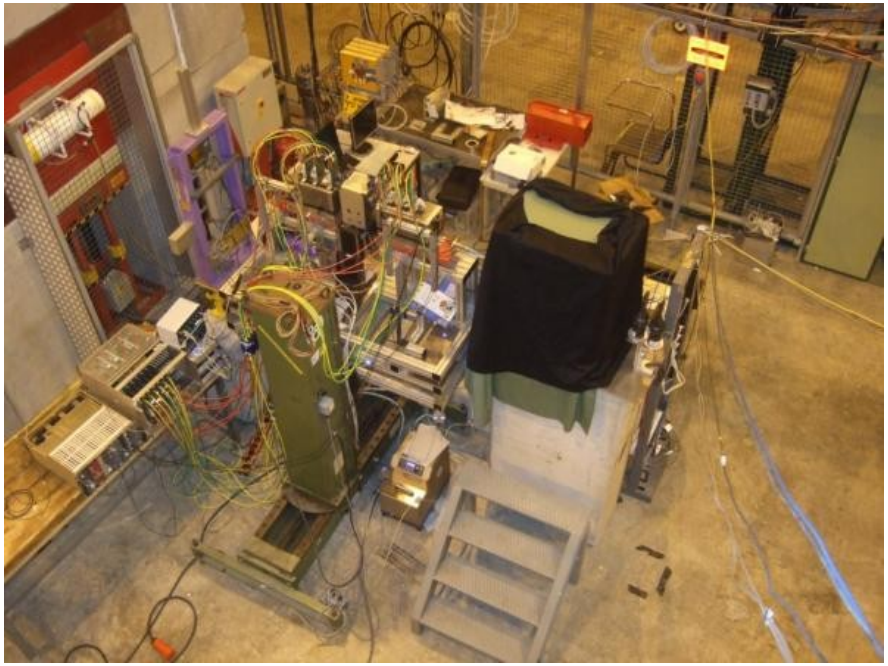
2009 Testbeam - Proving Timepix for LHCb

In early 2009 Timepix competing with Btev Fpix design to be upgrade baseline

Timepix had not been used at all in a particle tracking application

We took the opportunity to run parasitically in LCFI/EUDET and CMS beam periods

Running parasitically required us to provide a telescope, which led to this project.

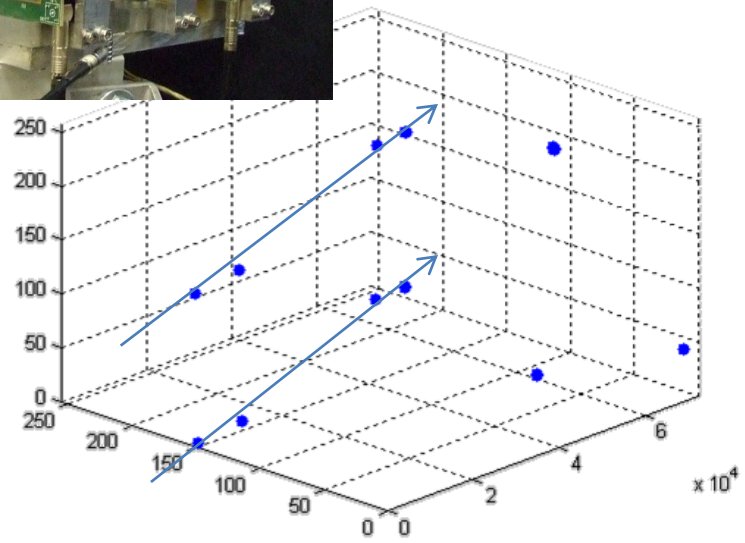


Main Measurements:
300um silicon and DS3D assemblies
Resolution vs Angle
Resolution vs Threshold
Resolution vs Silicon Bias
Efficiency vs Treshold
Efficiency vs Bias
Timewalk

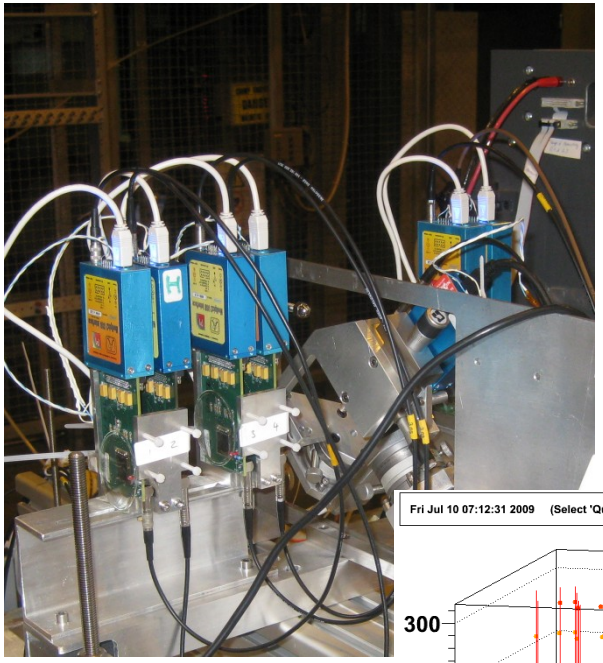
Early Telescopes in 2009

June 2009 : Medipix Testbeam
3 days to demonstrate tracking

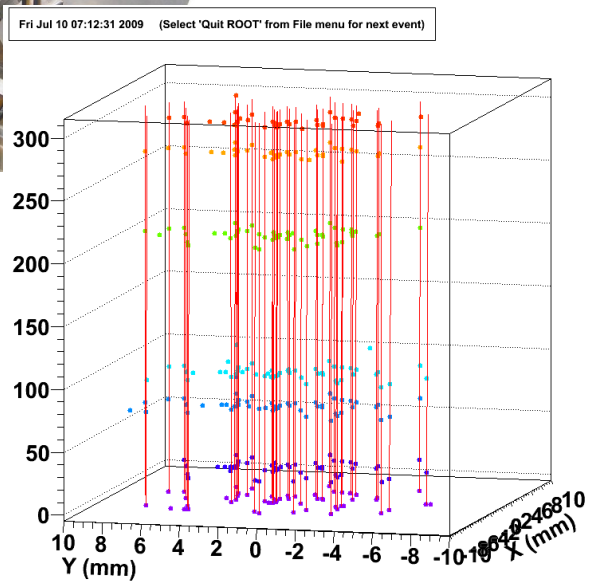
2 Timepix
2 Medipix
~perpendicular
No DUT



July 2009 : CMS SiBit beam period
Two weeks – parasitic Timepix Telescope



2 Timepix
4 Medipix
~perpendicular
300um and 3D DUTs
Manual angle adjustment

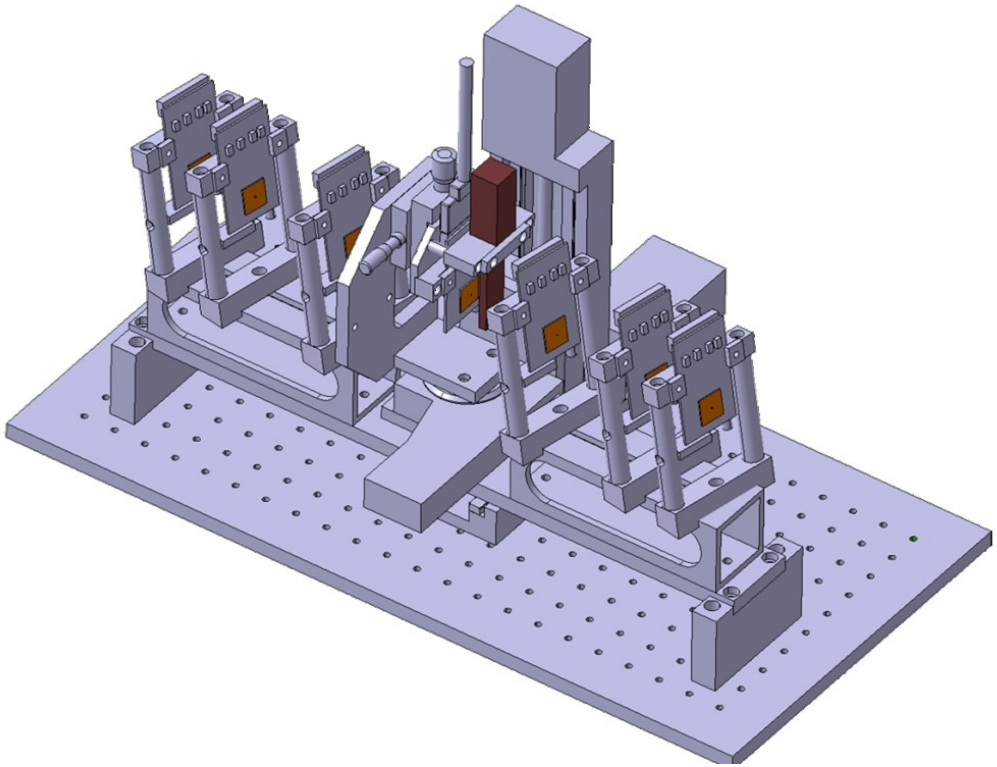


August 2009 Timepix Telescope

4 Timepix, 2 Medipix planes in telescope

Symmetric positioning of planes around DUT

Telescope planes mounted at nine degrees about x and y to boost resolution (next slide)



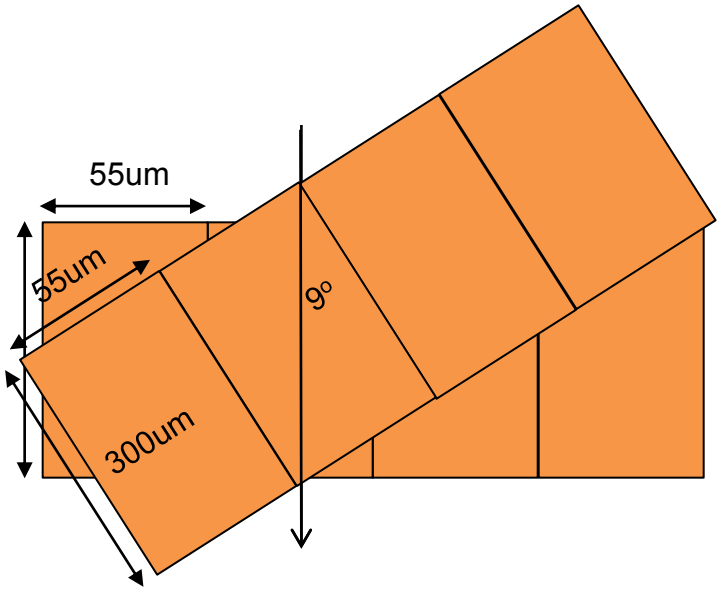
DUT position and angle controlled remotely by stepper motors

2.3um Track Reconstruction Error
~100Hz track rate
1 frame per second
~100,000 tracks per measurement point
~1.5 hours per point in SPS NA

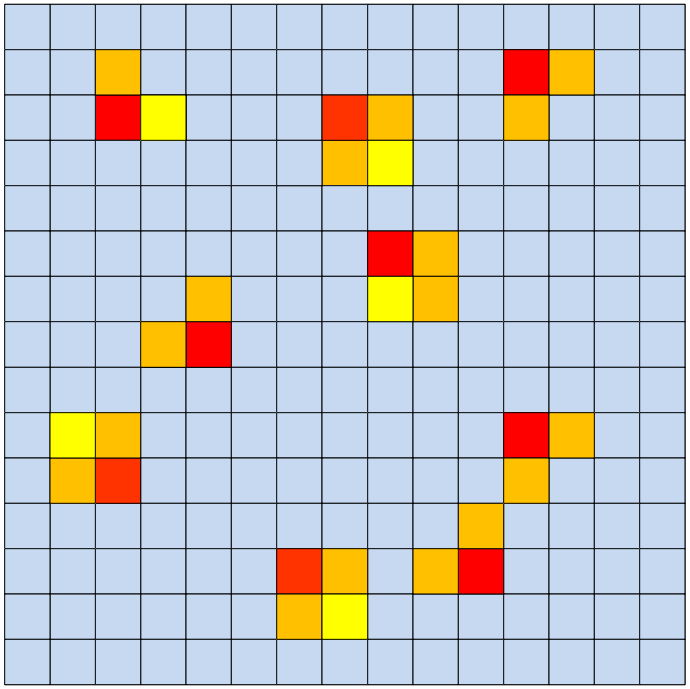
Angled Planes to Boost Resolution

Hits that only affect one pixel have limited resolution (30um region in 55um pixel)

Tilting the sensor means all tracks charge share and use the ToT information in centroid, CoG calculations



Perp ~10um resolution
9o ~4.2um resolution



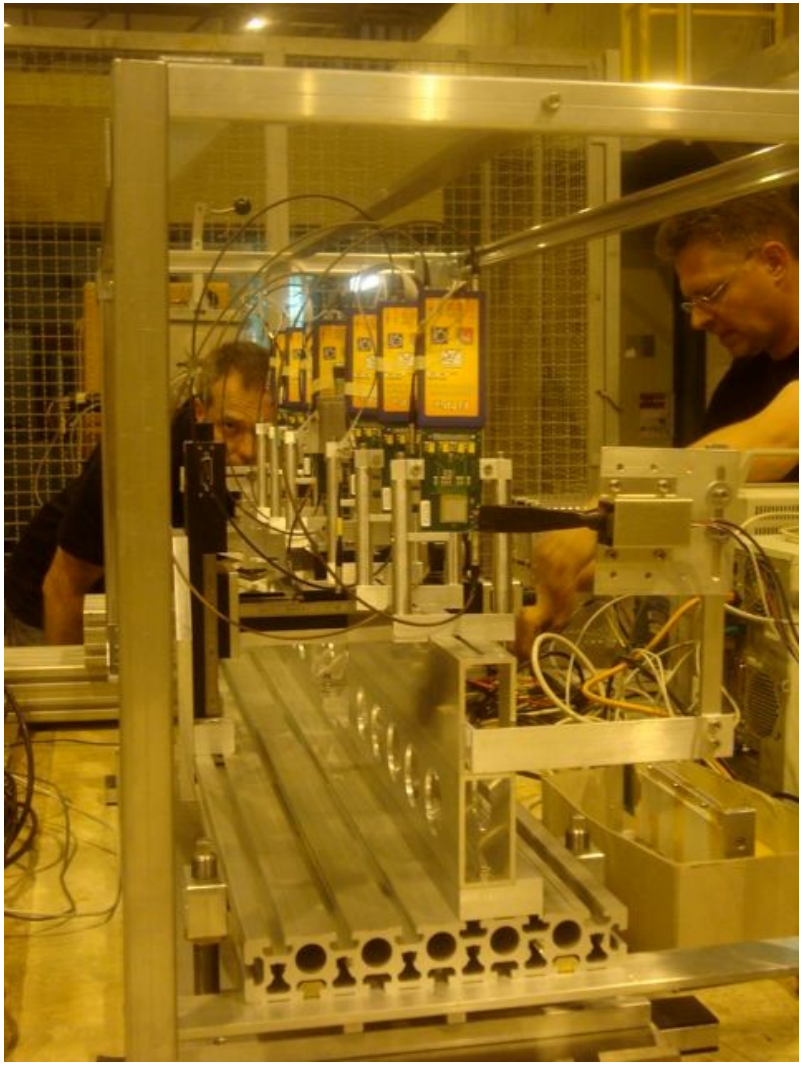
Indicative Timepix events

2010 Testbeam Activity

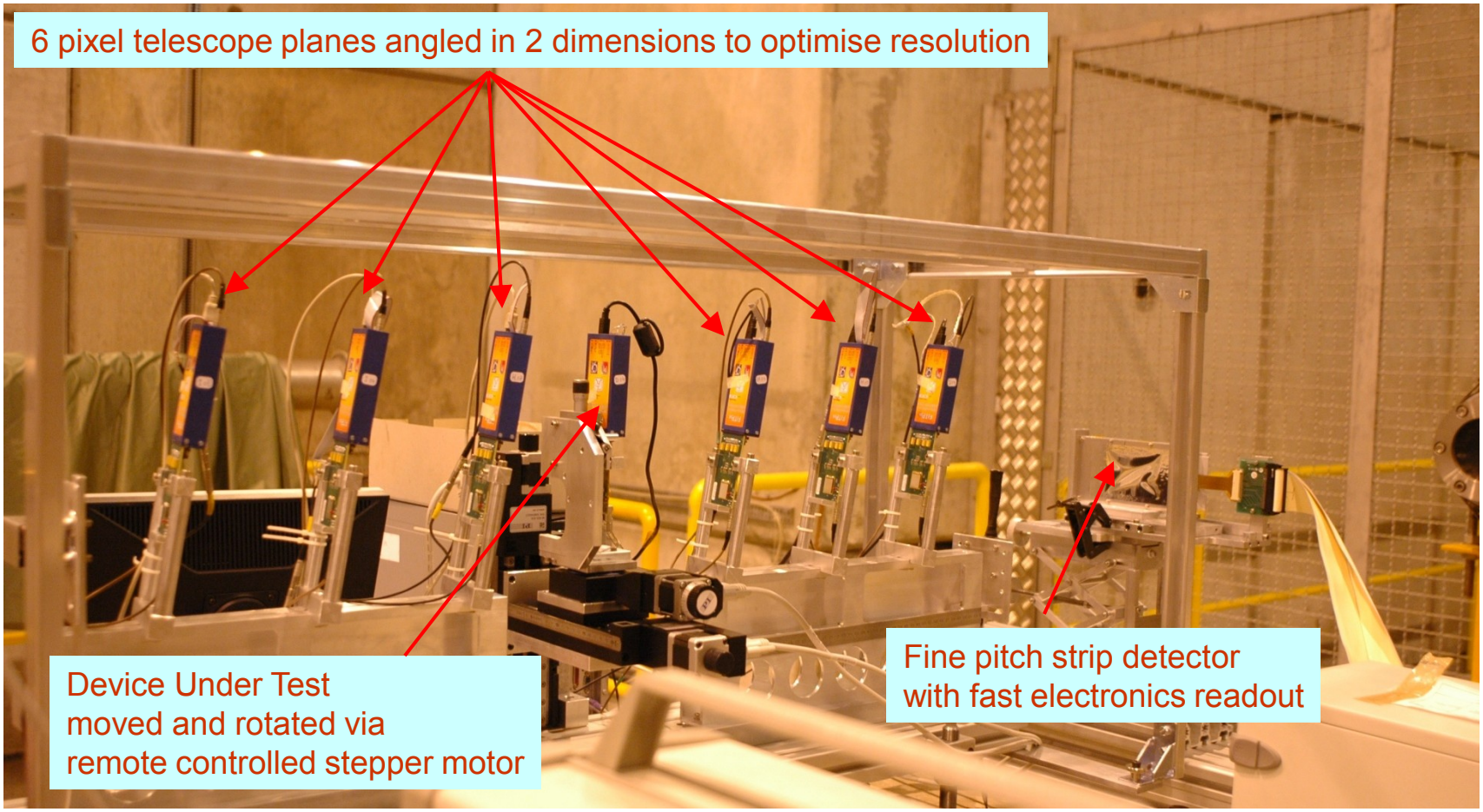
- Significant increase in activity
- 3 beam periods as main user

- Time Tagging System for 40MHz readouts
- USB2 and/or RELAXD readouts for faster data rate
- Up to eight Timepix planes for tracking
- More accurate and flexible mechanics

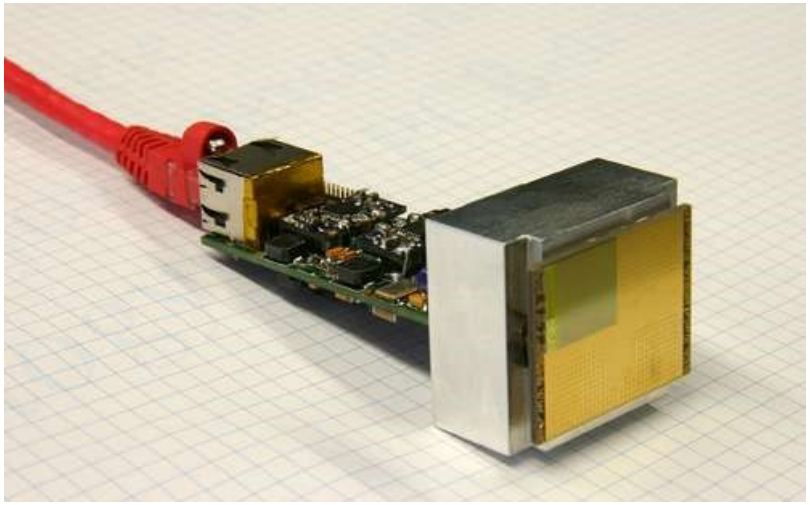
- Many Devices tested
  - LHCb VELO Prototype strip
  - DS3D irradiated Timepix,
  - Float Zone silicon Beetle strip,
  - BCB silicon Beetle strip
  - Magnetic CZ silicon Beetle strip
  - 150um silicon Timepix
  - 300um silicon Timepix



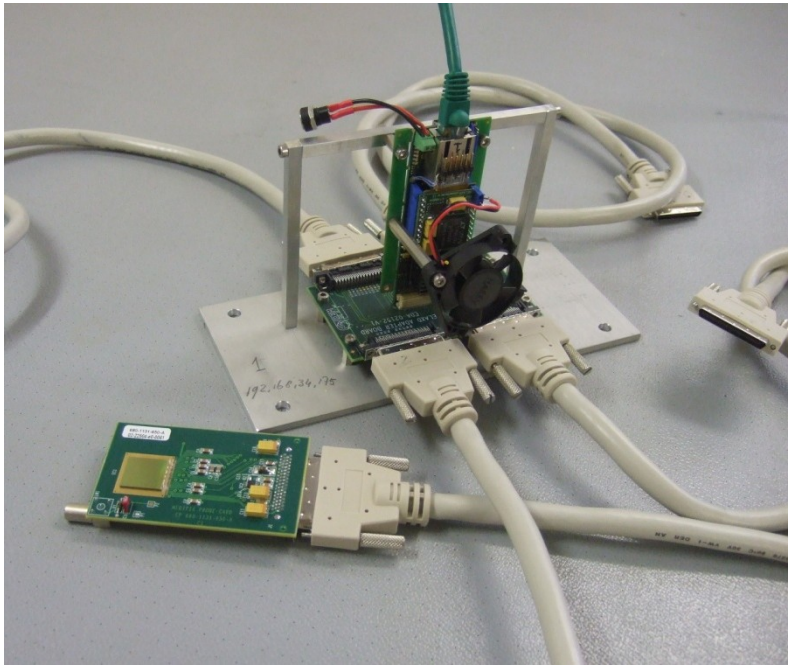
2010 Timepix Telescope - USB2 readout

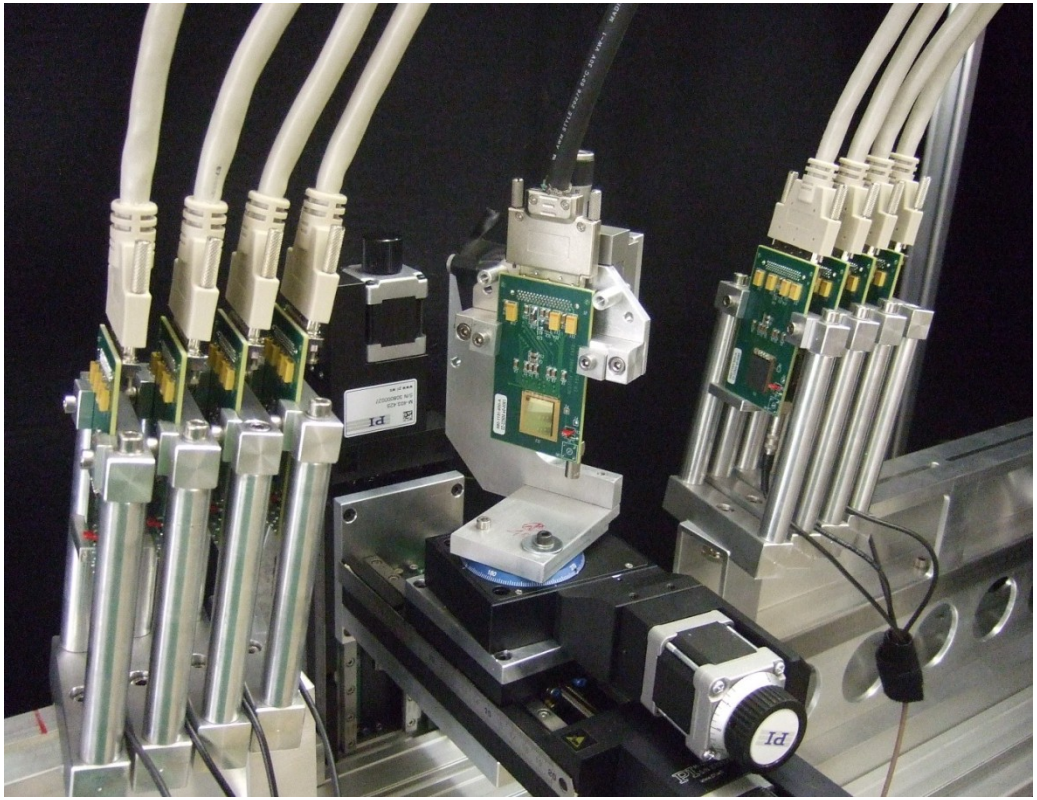


2010 Timepix Telescope - RELAXD Readout



- High **Re**solution **L**arge **A**rea **X**-Ray **D**etector
- RELAXD readout from NIKHEF
- 55 frames per second over gigabit ethernet





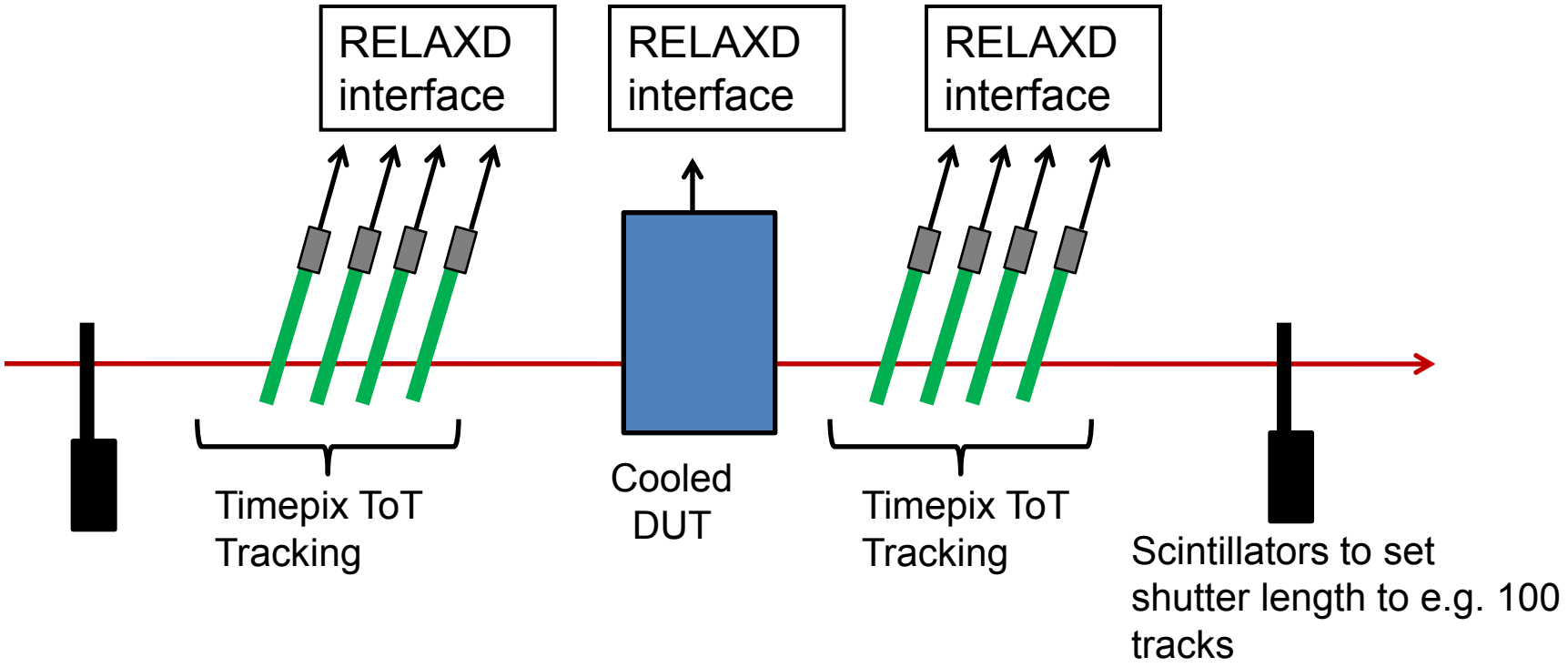
RELAXD Telescope – Timepix DUT

Optimised for resolution

Eight angled Timepix tracking planes gives a ~1.7um Track Extrapolation Error

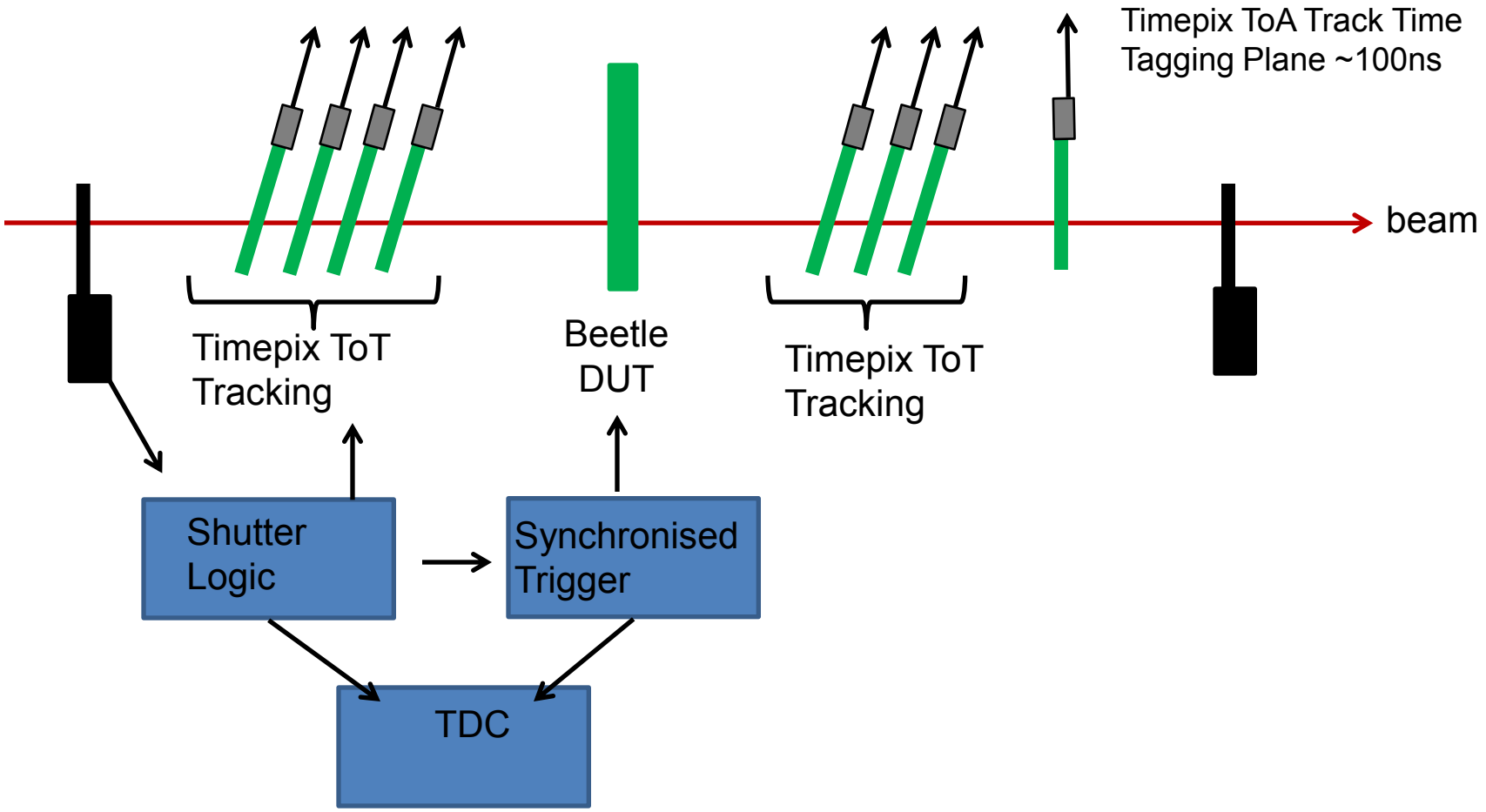
RELAXD system allowed 55 frames per second readout (~2,500 tracks per second)
Each 100,000 point measurement now takes 4 minutes at the SPS NA.

Closely spaced (~10mm) tacking planes reduce multiple scattering effects



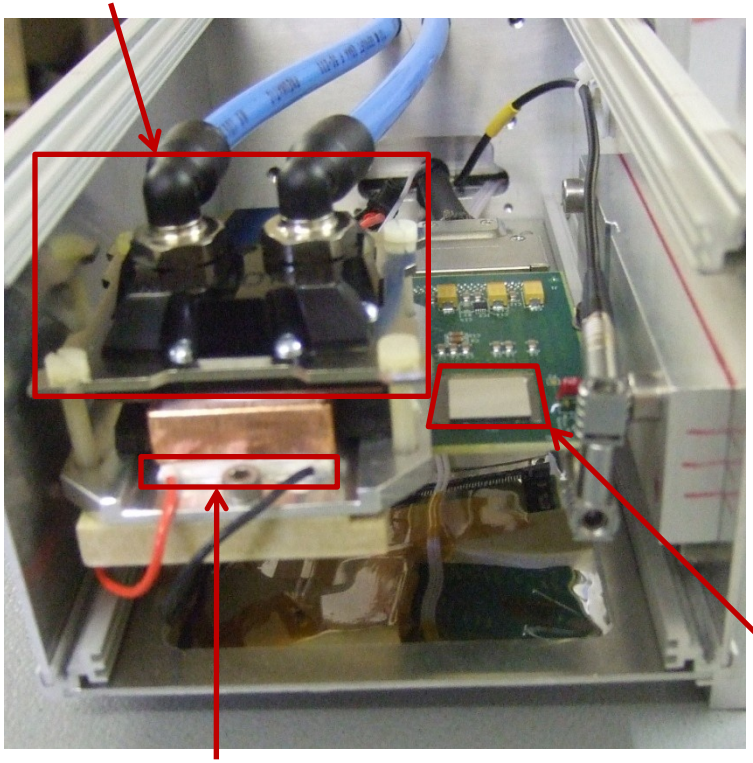
Time Resolution for LHC readouts

- Asynchronous SPS beam not suited to LHC systems designed for 25ns bunch structure
- Implemented a TDC which with Timepix ToA mode gives us ~1ns per track time stamping
- Able to provide and record synchronised triggers to 40MHz readout systems (TELL1)
- Allows software reconstruction and analysis of asynchronous tracks

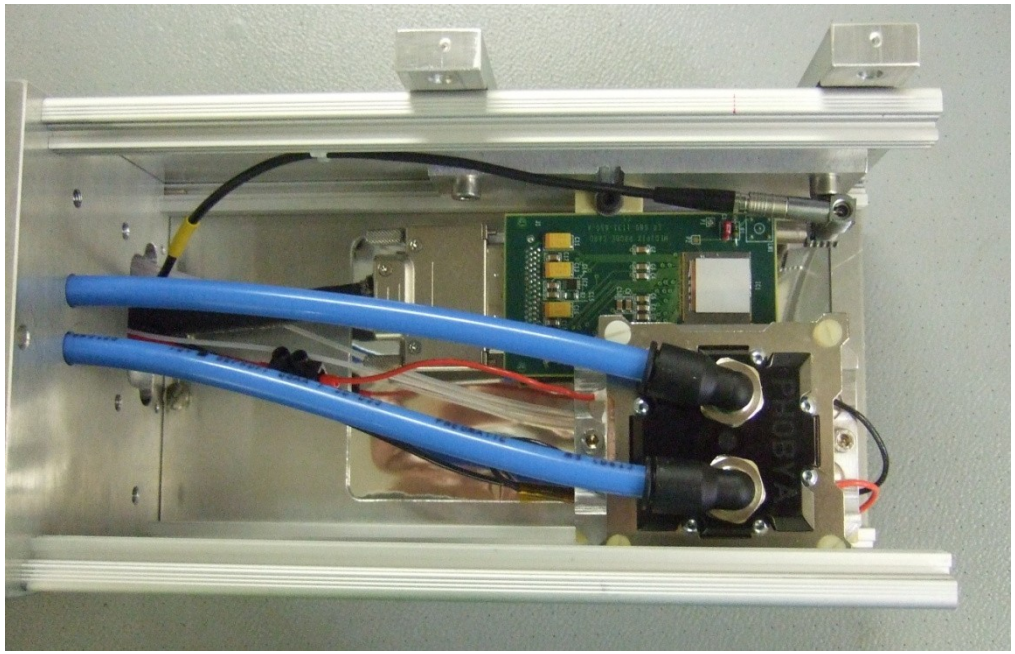


Cooling System

Water Block



80W Peltier

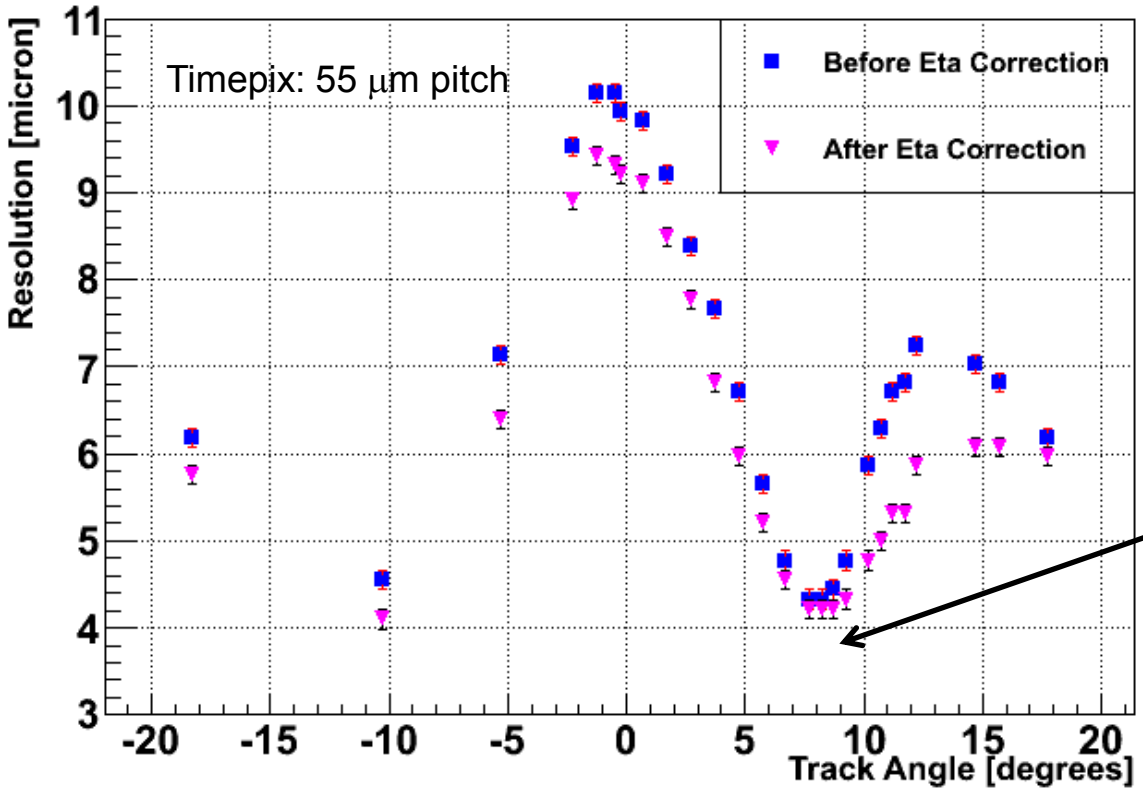


Chip and Pyrolytic Graphite

To operate irradiated assemblies its necessary to cool the sensor to below 0°C

This system achieved a steady temperature of ~-5degrees

2009 Results – Resolution Vs Track Angle

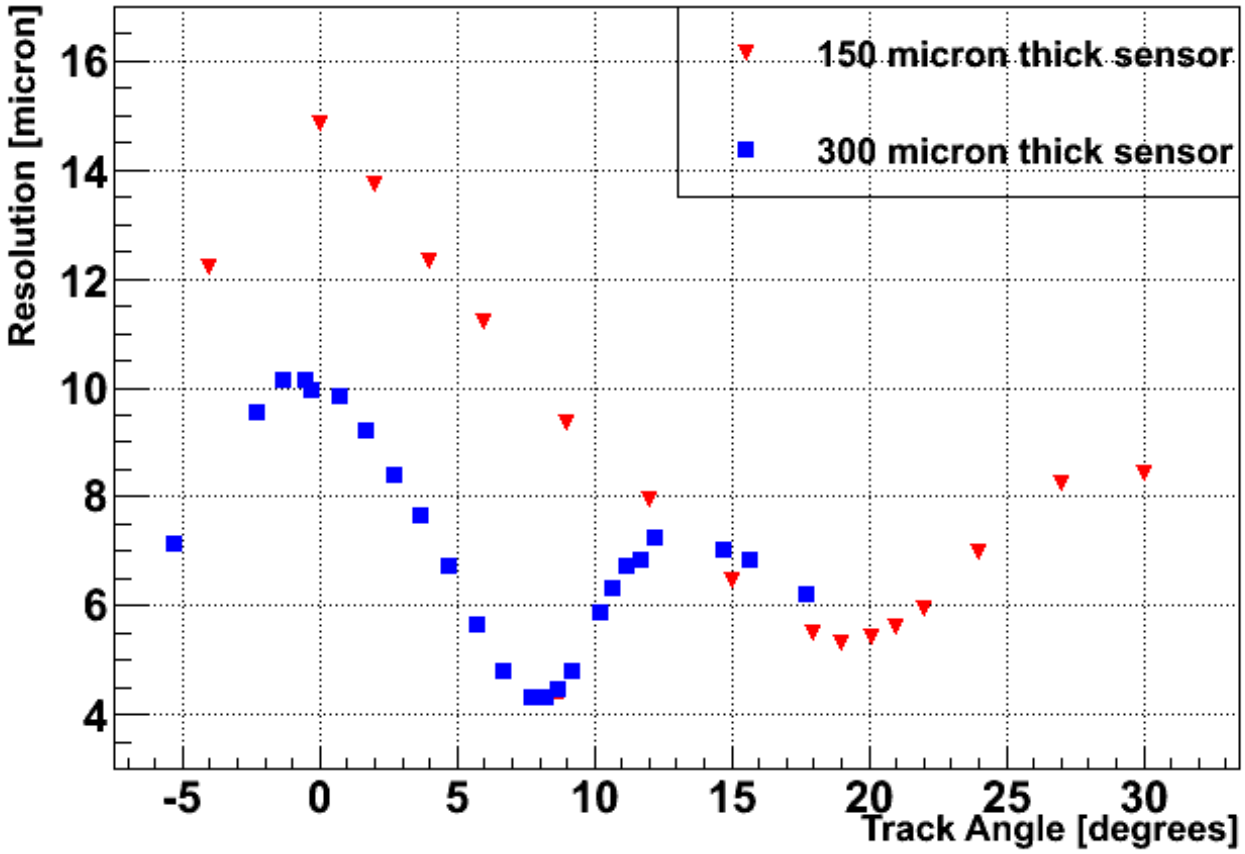


Operating point of Telescope planes

Resolution result from 2009 testbeam demonstrating resolution of a Timepix assembly and the performance of the telescope

Confirmed Timepix (VELOpix) as baseline for the VELO upgrade

2010 preliminary - 150um Sensor Results



With a 150um sensor the optimum resolution point is at twice the angle of a 300um

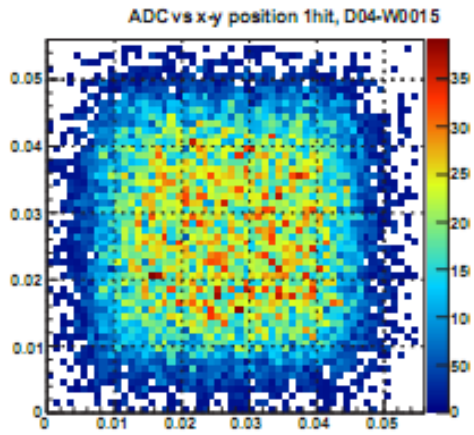
The higher data rate has allowed a significant number of measurements to be taken

Sub Pixel Resolution

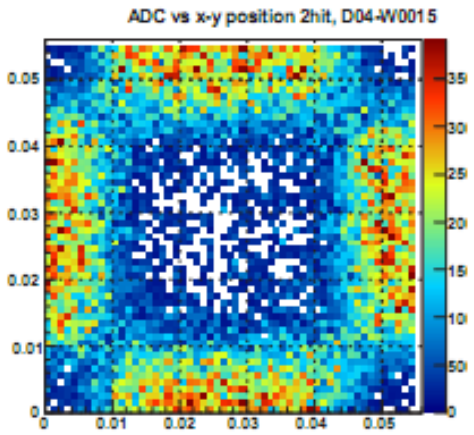
What can we do with so much resolution?

An example of different cluster sizes for the track position in the pixel

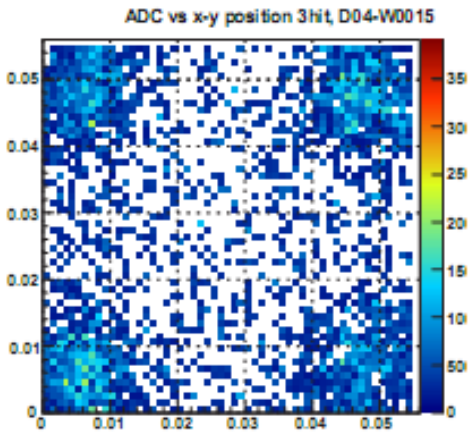
One pixel clusters



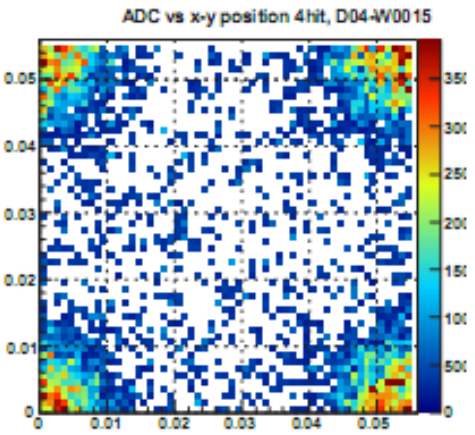
Two pixel clusters



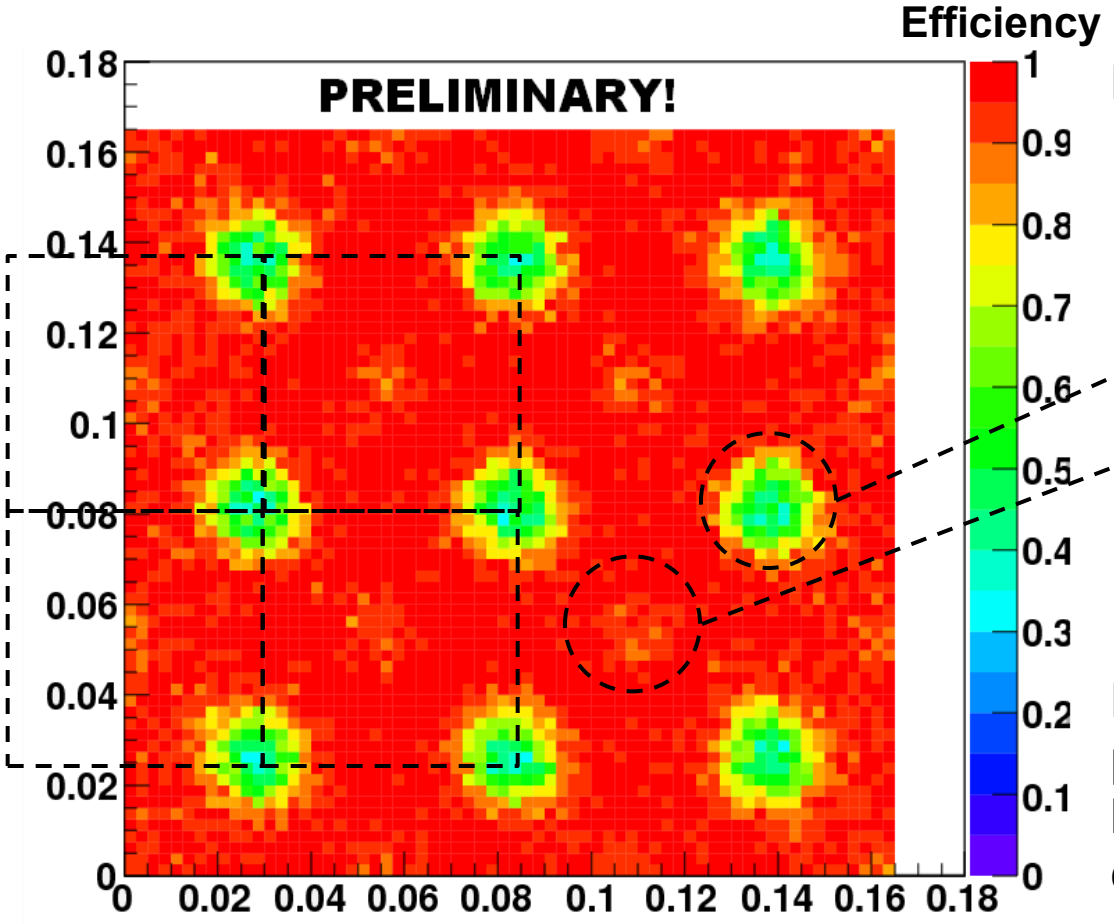
Three pixel clusters



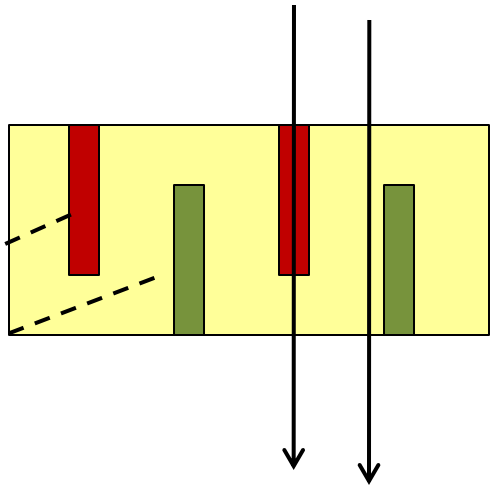
Four pixel clusters



2009 Results – 3D Sensors



Double sided 3D sensor

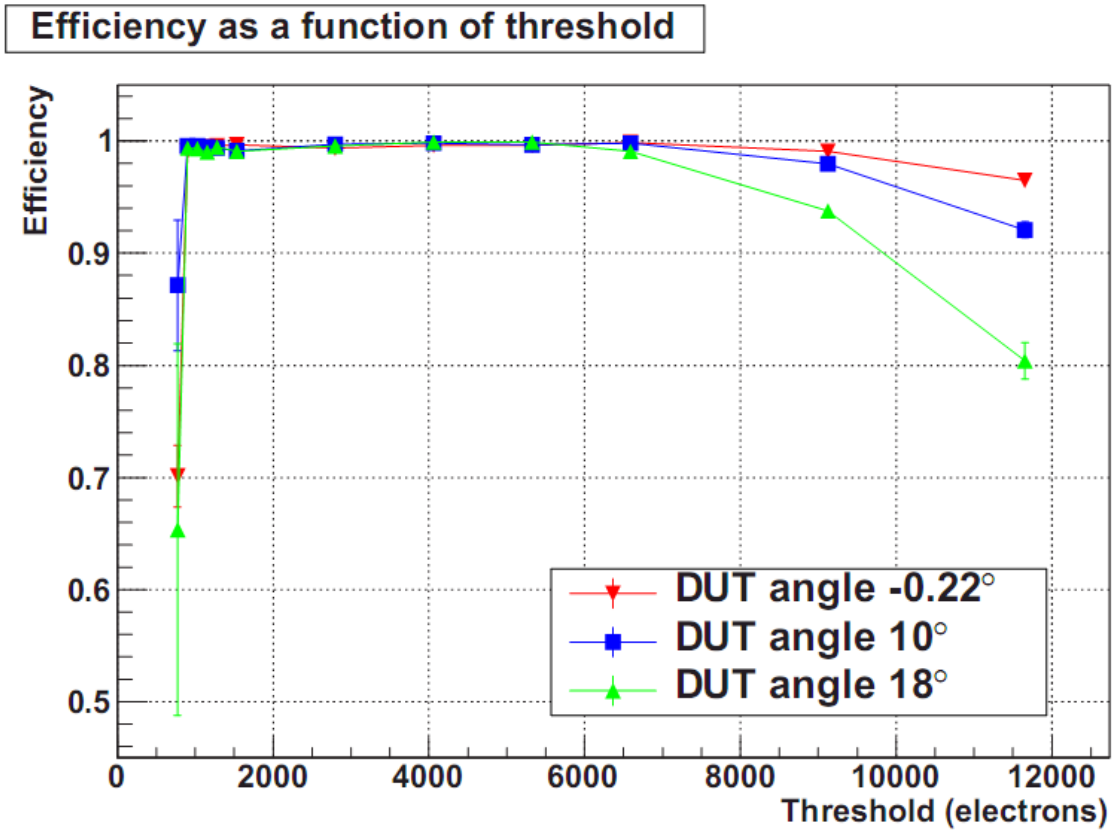


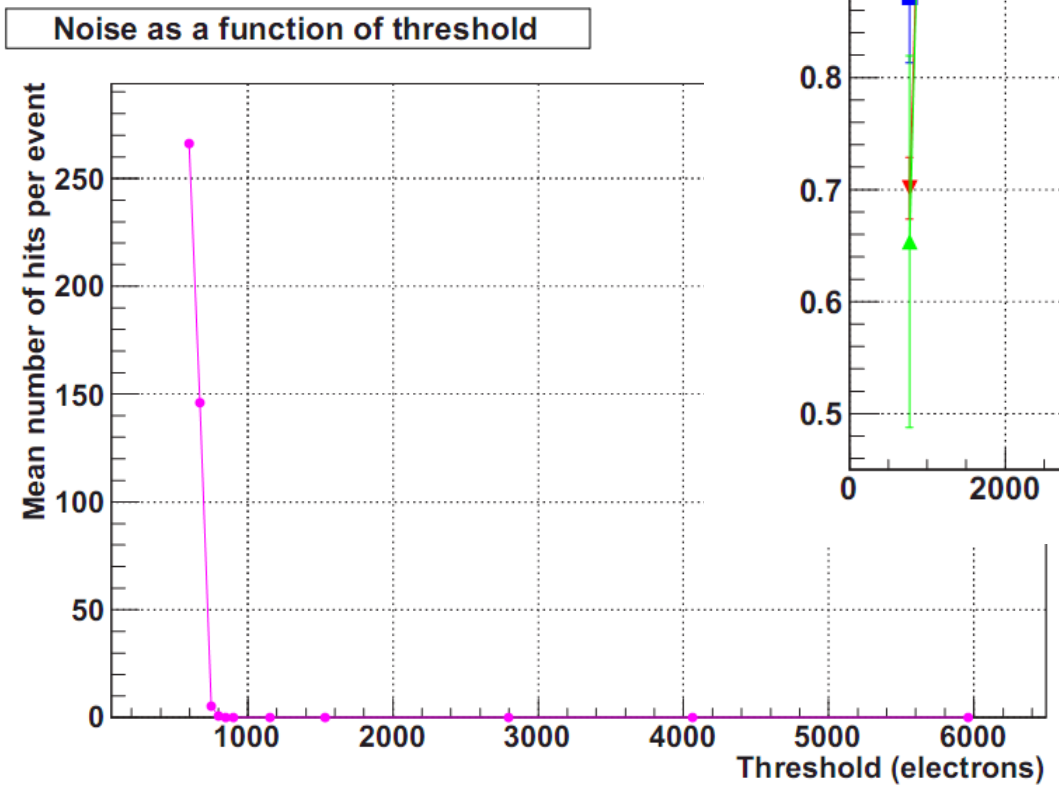
Perpendicular particles passing through a doped hole will deposit less charge in the silicon

The sub-pixel resolution of the telescope allows us to see the efficiency losses due to the anode and cathode wells in the silicon.

Efficiency & Noise

The Efficiency is measured at ~99.5% when operating above nominal threshold





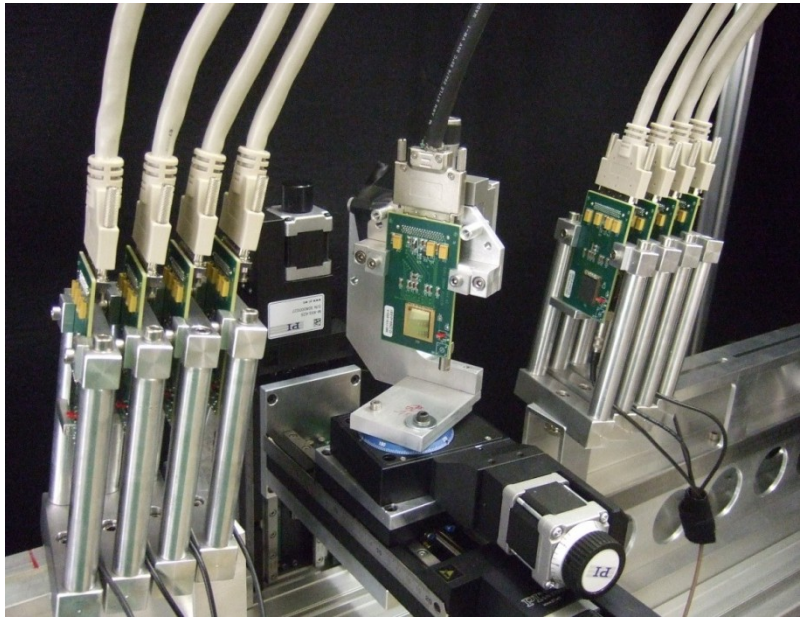
The noise is 0 above 800 electrons

Below 800e the efficiency falls due to the discriminator architecture

Telescope Comparisons

Telescope	Pixel	Resolution	Time Tag	Rate
Timepix 2009	55um	2.3um	100ns	100Hz
Timepix 2010	55um	1.7um	~1ns	2.8kHz
EUDET (low res)	18um	~2um	100us	990Hz
EUDET (High res)	10um	~1um	-	300Hz?

EUDET Telescope



Telescope Project Membership

A joint project between the Medipix2 and LHCb VELO Collaborations

Specifically:

- Timepix – CERN Medipix Group
- Mechanics – CERN LHCb Group & Santiago
- Timepix Readout – NIKHEF & Prague CTU
- Beetle Readout and DUTs – Santiago and Glasgow
- Synchronisation Systems – CERN, Glasgow & Santiago
- Analysis Software – Oxford & CERN with many other contributions

In addition the results presented here included significant effort in both data taking and analysis from Syracuse, Liverpool and Erlangen

Using the Telescope

- Currently working to make it generally available to LHCb community as a whole for Consolidation and Upgrade work

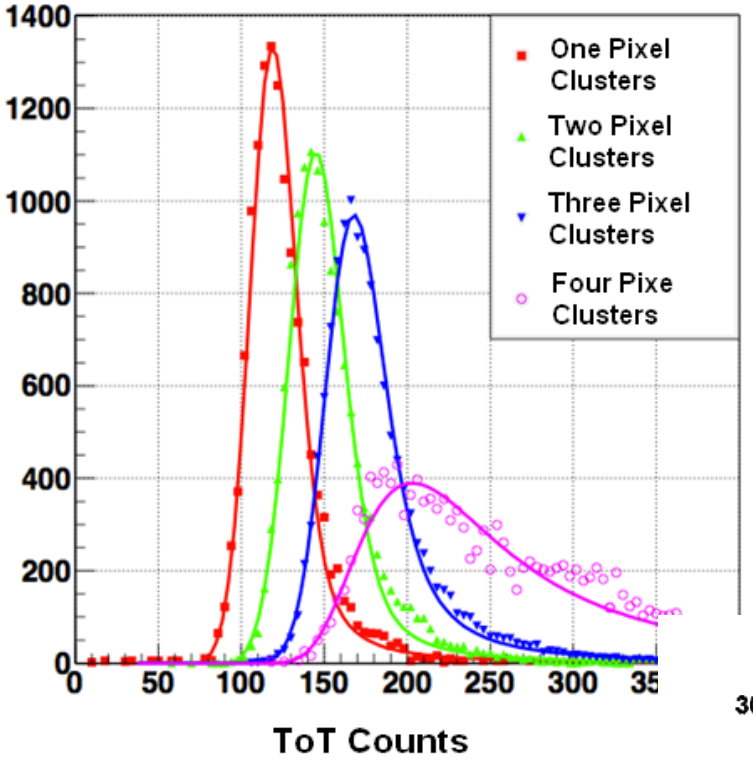
- Would also like to offer it as a tool to anyone interested here
- Working hard to commoditise the system and keep it small and portable
- Can provide significant expert support and help with setup and software
- Subject to other commitments next year obviously

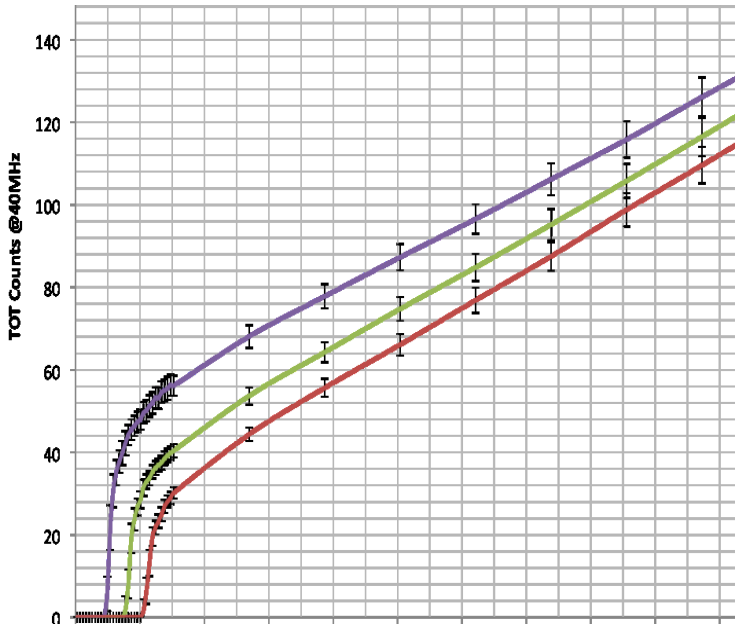
To Conclude

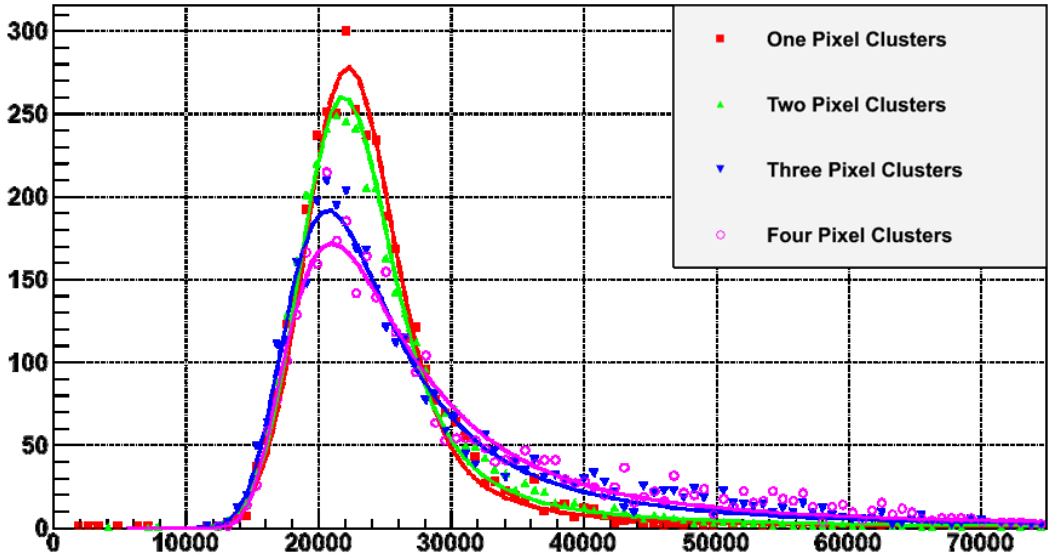
- The Timepix Telescope is now extremely competitive in resolution and rate
- System provides ~ns accurate time tagging in an asynchronous beam
- First results about to be published and looking very encouraging
- Capable of integrating 40MHz readout systems and making clock phase measurements
- Integrated DUT cooling system used this year and being upgraded to CO2
- Very happy to discuss using the telescope with other groups

Backup Slides

2009 Results - Timpix ToT Calibration

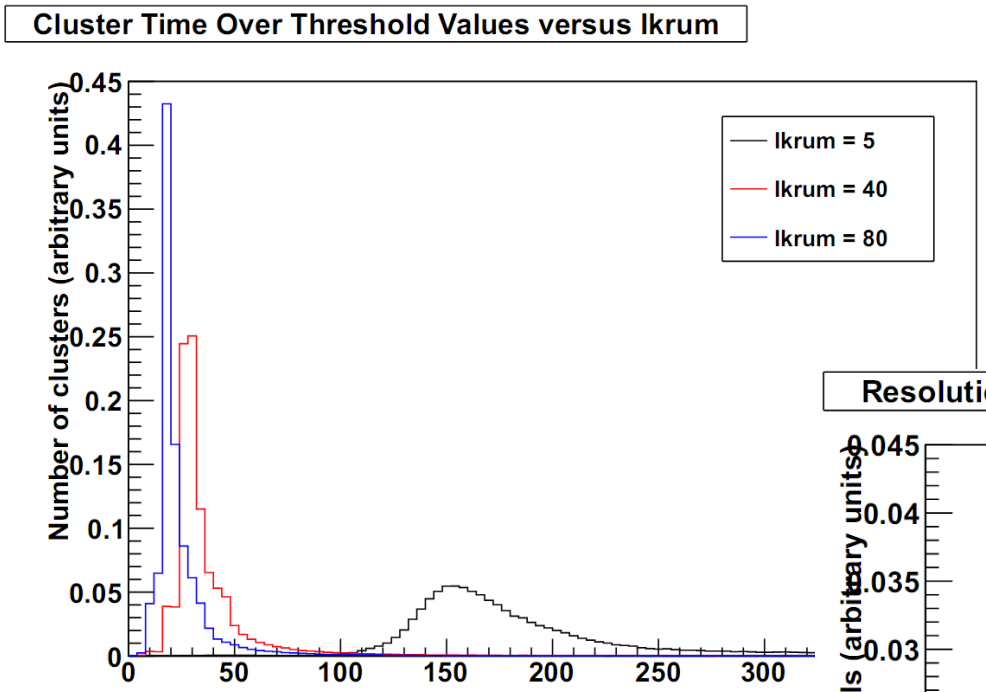






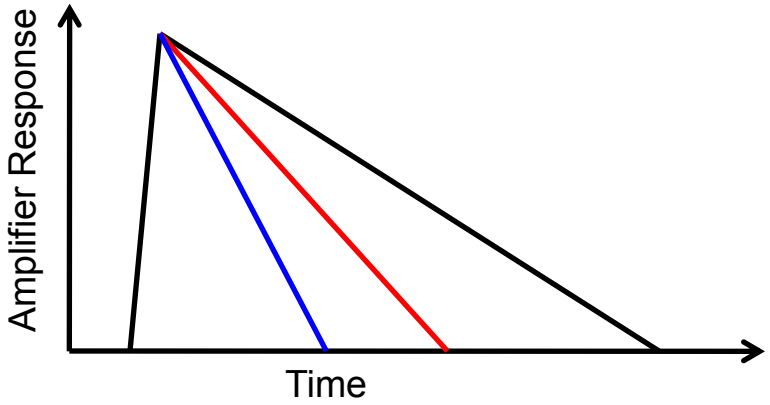
Energy mapping of Timepix calibration is now confirmed with MIPs

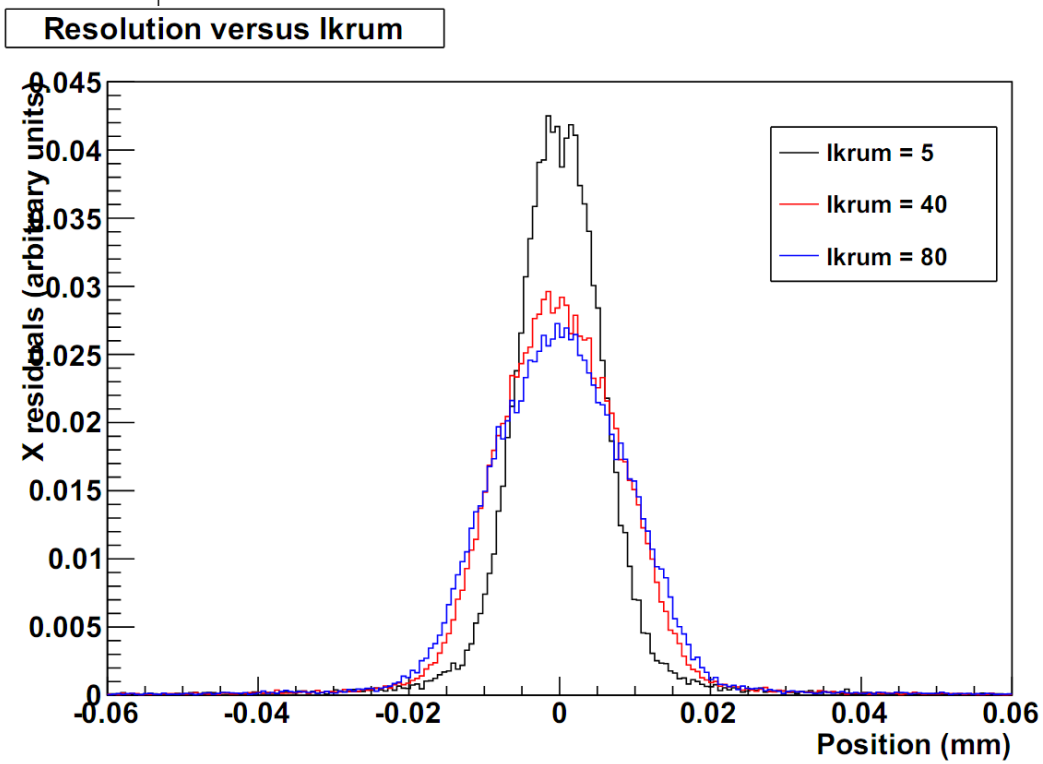
Results 2009 - Ikrum Variations



As Ikrum varied, change in ToT range observed and some loss in resolution

PRELIMINARY - analysis by D. Hynds





2010 Telescope in Timepix DUT Configuration

In this configuration the telescope was optimised for running with a Timepix DUT

The USB2 readout allowed a 7 frame per second readout rate (700Hz track rate)

The all angled six Timepix telescope gives a ~2.0um Track Extrapolation Error