# The FE-I4 telescope

Branislav Ristic and quite a lot of other people 20/01/2015





### Motivation

- ATLAS Pixel sensors R&D devices based on FE-I4 readout chip
- Former testbeams using EUDET Telescopes
  - High resolution
  - Lots of experience and great support
  - ...but rather complex system (TLU, separate ROI trigger plane)
  - Shutter based readout (telescope) ↔ trigger based readout (FE-I4)
  - FE-I4 reference plane
- ...and we wanted our own telescope
- Goal: Build telescope based on FE-I4 planes
  - Fully synchronized with DUT
  - Portable
  - Fast
  - Compatible to EUDET mechanics and EUTelescope



## The FE-I4 telescope

The telescope

- 6 pixel sensor planes in two arms
- Sensors: IBL double chip sensors (200um n+-in-n, 250x50um Pitch)
- Readout: FE-I4 (40MHz sampling, 4 bit charge resolution (ToT), trigger based)
- Trigger: First and last sensor plane, easy generation and application of masks

Mechanics

- Two movable arms hosting 3 planes each
- Planes can be tilted around x and y
- XY stage with DOBOX style DUT box
- Cooling by chiller or dry ice possible

Speciality

- Sensor pixels not square shaped
- Middle planes of telescope arms tilted by 90° around beam axis

20/01/2015



DAQ: HSIO (High Speed IO) / RCE (Reconfigurable Cluster Element) system developed at SLAC

- HSIO: FPGA board interfacing telescope and DUT FEs, trigger handling
- RCE: Power PC based computing units
- DAQ PC: Laptop running SLC 6 and custom C++ based software
- Extensively used for IBL production and commissioning
- Basic functionality already implemented for cosmics telescope at SLAC
- Highly extended for testbeam in terms of performance and stability
- Data output in Judith ROOT format, EUDET raw format and RCE raw format

Services/DCS

- Small movable rack
- Programmable HAMEG LV and Keithley/Iseg HV power supplies
- NTC and humidity sensors
- All remotely controllable by LabView interface



### Schematic overview









### User interface

#### Hardware

- FE-I4 device: RJ-45
- All other devices: trigger output, busy input line, both LVTTL over LEMO

#### DAQ

- ROOT/Qt based GUI
  - Planes/DUTs can be added and configured individually
  - Readout windows (Number of Lv1A) and delays can be set seperately for telescope and DUTs
- Plain text configuration files
- Setup via one shell script
- In case of a failing DAQ (very unlikely): Recovery via one shell script

#### DCS

- LabView GUI controlling power supplies, stages and chiller
- All data is logged in plain text files

vlain Config Testbeam Monit	oring	1						
	Global	Module Configuration						
Update Save Save A:	S Load Config Name: H	HVCMOS_2014_07_v2_telOnly Key	<b>/:</b> 93					
Config Root Dir:			A	bs Path Bro	owse			
Data Dir: /auto/2t-ext-tbdata/rcedata/RunData				Bro	owse			
Run Number:		1414 📩						
atency: 8 - Consec. Tras:	16 - Tra Delay: 223 - De	eadtime: 250 🛋						
Running	Trigger Sources Scihilitators Extendet Trg Extension Feld HB Cyclic Trg Cyclic Period (ticks)	Schullators Discrim Discrim Logic Discrim NAND0 Discrim NAND1 Discrim NAND2 Discrim NAND3 Hitbus NAND3 Hitbus NAND3 Discrim Discrim Discrim Discrim Discrim Discrim Line Discrim Discrim Discrim Discrim Discrim Discrim Line Discrim Manual Discrim Line Di	G	Format: Eudet Raw ROOT uit				
		File Edit View Project Operate	Tools Window	r Help				- -
Fime: 1133 s Events: 1963	43 Total Rate: 171.71 H	Overview High voltage Low/Mid vo	oltage Temp/H	umi Chiller Stages	1			<b>A</b>
		151	EG			CAN opened ?	Unistat_slider	
		намев 🔾 🥏 📗	O TEL	-FO	80.0 V BI	ue slider=target ten	nperature, Red slide	er= ourren
		KETTHLEY_2410_0 🥚 🌑	1 18.	-F1	80.0 V	2.088 uA	40	
	D.B.	KETTHLEY_2410_1 😑 🕖	2 TEL	-F2	80.0 V	1.225 uA	35	
		KEITHLEY_7001 🥹	3 TEL	.01	80.0 V	1.291 •	30	
		ISEG 🕒		87	0.1	1254 uA	20-	
		N06019_0 🕒	6 DU		0.1 v	1.568	15	
		N06019_1 🔾	7 DU		0.1 y	0.000 uA	10	
		CHELLER 🔴 🌔 HJ	AMEG	,,		un	5-	
		STAGES 😑 🌔	0 LV-TEL-	FRONT	2.2 V	2.105E+6 uA	-5-	
a arriva t			1 LV-TEL	-BACK	2.2 V	2.221E+6 uA	-10	=
ISCHOL		Stop	2 DUT-	I-Vssa	5.0 V	4.900E+4 uA	-15	
1		Rescan devices	3 DUT-:	-Yssa	5.0 V	4.920E+4 uA	-20-	
		Online plots KE	ITHLEY_0				-20-	
		Start Monitor	0		V 0.0	0.000 uA	-35 Target	
		Monitoring enabled ?	Chlop	ened		1	-40 0.0	
		5 Monitoring delay (s)	•		0.0 V	0.000 uA	-45 Current	
		uri	Chlop	ened 🛛	Ch2 opened		-50-	
		remote filename	16009_0	Mahar II 2	N86009_1	Name		
		currentRun.txt	0 TEL-F0	25.6 C	0 B	ox Humid #1 SR.	1 % RH	
		http connection OK?	1 TEL-F1 2 TEL-F2	33.9 C 25.0 C	1 B	ox Humid #2 52.	2 % RH	
		DCS output path	4 TEL-B2	33.2 C	4 8	lox Temp #1 28.	.6 C	
		Contractors 2	5 TEL-81 6 TEL-80	26.8 C 24.9 C	5 0	ox Temp #2 27.	a c	
		1414						

# Telescope features and performance

- Built May 2014 and commissioned July 2014 in the PS T9 testbeam
- Currently 2 DUTs supported (will be extended)
- Telescope practically noise free
- Trigger frequency in SPS H8 beam (average during spill)
  - ~17kHz trigger rate with one DUT (upgrade ongoing)
  - ~4kHz triggering on 3% of FE-I4 (720 pixel)
- Resolution at DUT: ~8μm x 10μm
- DCS and DAQ hardened
  - ~1 problem/crash per week
- All remotely controllable
- Plug&Play for FE-I4 devices
  - Not much more difficult for others







### ROI trigger

- ROI defined by plain text mask
- Mask generation by Python/Bash scripts
  - Rectangular mask by x/y range
  - Arbitrary mask from png file
- Used successfully for HVCMOS CCPD (~3x4um<sup>2</sup>) devices





- Multiple flavors of ATLAS HVCMOS sensors
- IBL like modules (Track separation studies)
- New planar pixel sensors

Non-FE-I4 devices

- Efficiency studies of DAMPE strip detectors
- Commissioning and performance measurements with new strip detector readout from KEK

Additional devices: maybe yours?



### Upgrades

- Resolution: Tilting of planes
  - Already some data taken  $\rightarrow$  Will be analyzed soon
- Speed: HSIO firmware upgrade ongoing
- Functionality: New adapter card interfacing the HSIO to the FEs
  - Up to 32 devices
  - Added CMOS lines (direct configuration of HVCMOS devices) → Has to be implemented in SW
- DCS: Unification of power supplies in Mpod crate
  - 16 0-5V LV channels
  - 8 0-120V LV channels
  - 8 0-2kV HV channels





### Summary

### A new FE-I4 based telescope has been built and commissioned

- Rather simple system
- Synchronized readout (no reference/timing plane needed)
- High trigger rate
- Resolution ~8-10µm
- ROI
- Stable and simple to use DAQ
- Plug&Play (for FE-I4 devices)
- Lots of data has been taken during last year
- Similar telescope built by ATLAS Inner Detector group at CERN

A huge thanks goes to Martin Kocian for his continuous effort on improving the telescope and support for data taking and Garrin McGoldrick et al. for the Judith reconstruction framework

