Test beam characterization results with HV-CMOS sensors capacitively coupled to FEI4

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on behalf of the ATLAS HV-CMOS UniGE collaboration

Introduction

- A major upgrade of the ATLAS detector is planned for the HL-LHC

- The currently installed inner detector will be replaced with a full-silicon tracker (ITk)

- High-Voltage CMOS (HV-CMOS) is a candidate technology for the outer pixel layers of ITk

Requirements: Fast & Efficient (>95 % in 2 BC after irradiation)

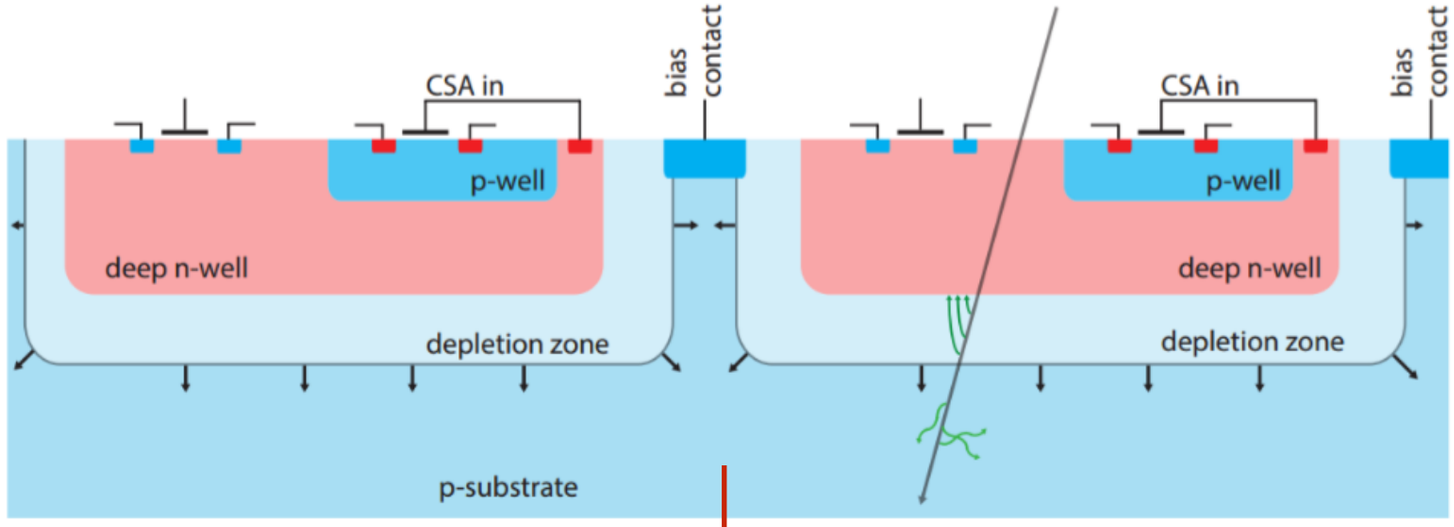
- HV-CMOS sensors have been studied extensively during the last years:

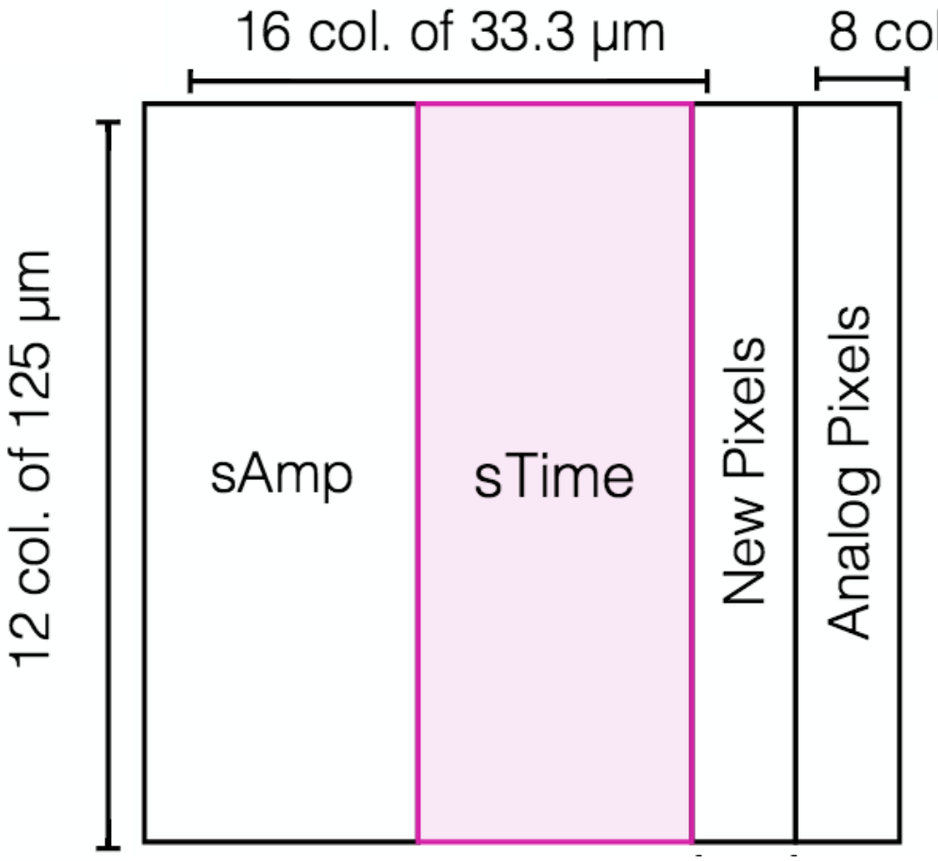
OUTLINE of the presentation:

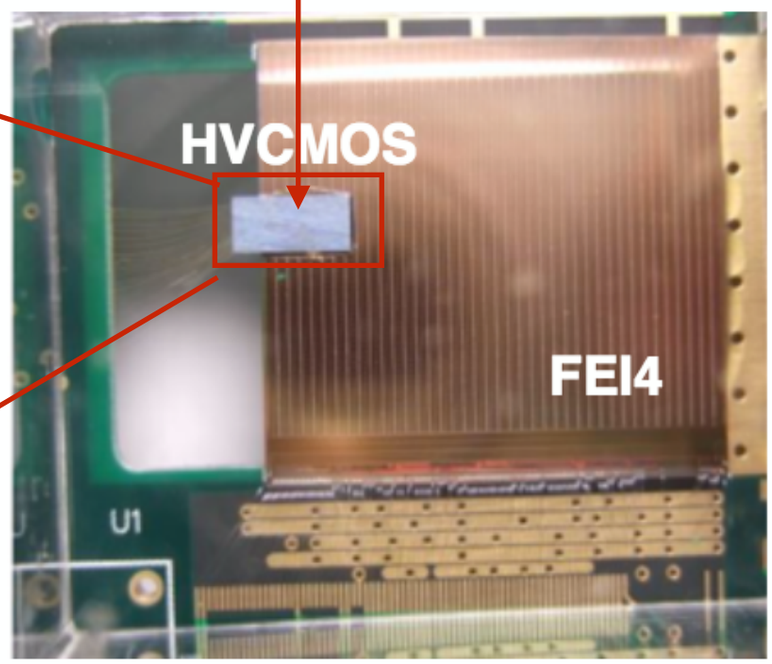
1. The HV-CMOS technology
2. The DAQ system
3. The FEI4 UnigE Telescope
4. Test-Beam results from the CERN SPS

Capacitively Coupled Pixel Detector (CCPD)

- HV-CMOS sensor are connected to the read-out chip (FEI4) via a layer of glue ->no bump-bonding
- HV-CMOS Pixel Unit cell is 33 x 125 um



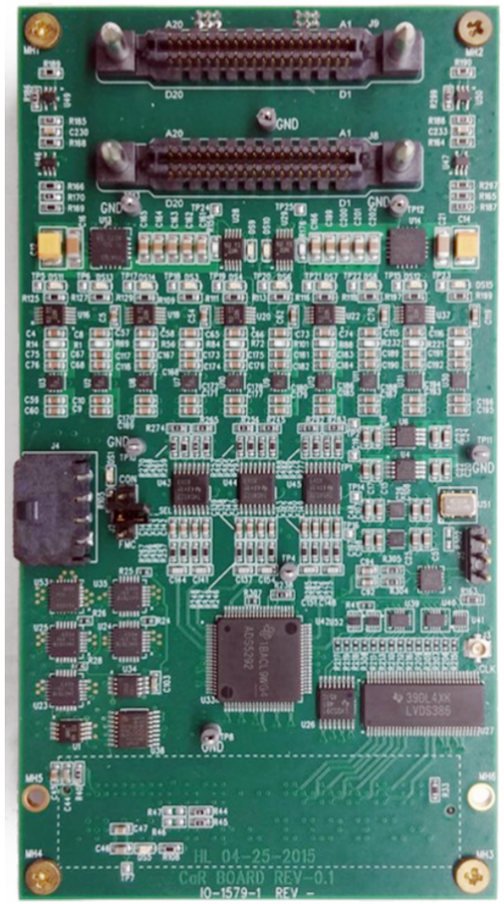




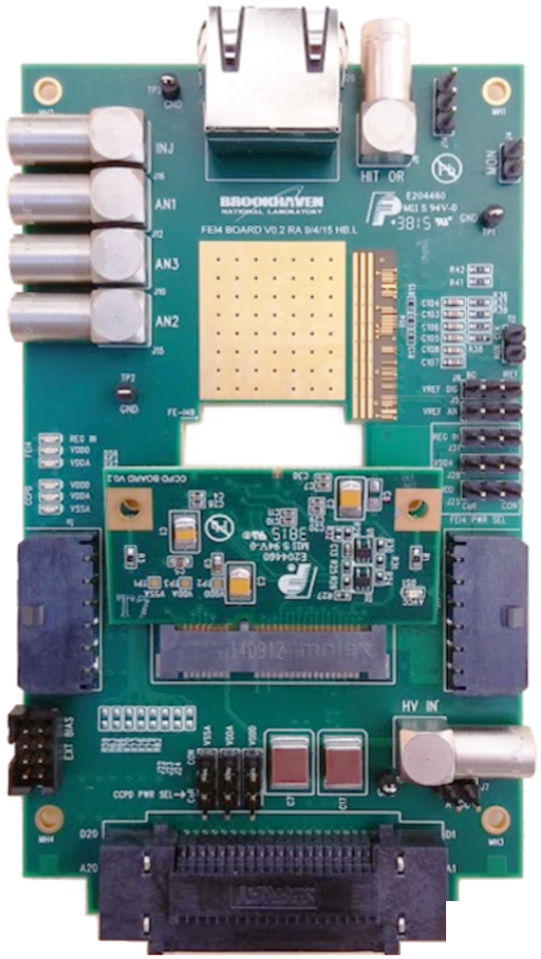
CaRIBOu system

- A modular readout system for HV-CMOS sensors
  - CaR board: Power rails + LVDS Receiver/Transmitter + Level translators + DACs
  - FEI4 Board: HV input + Bonding pads for FEI4 + Circuits for FEI4 and CCPD

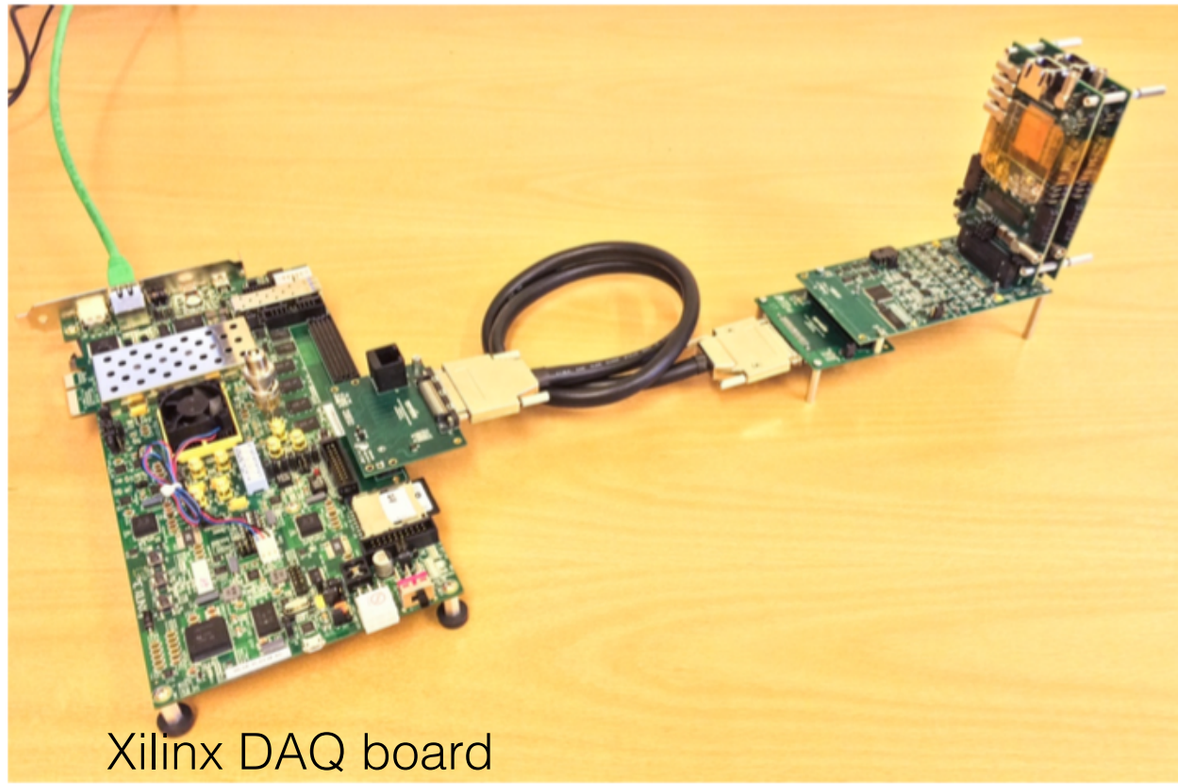
CaR Board



FEI4 Board



Full system



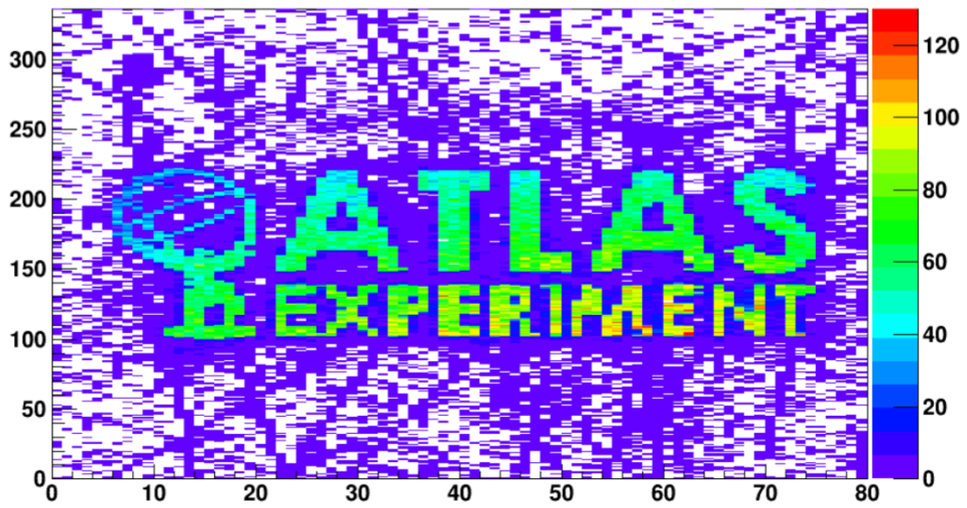
arXiv:1603.07950

arXiv:1603.07776

The FE-I4 Telescope

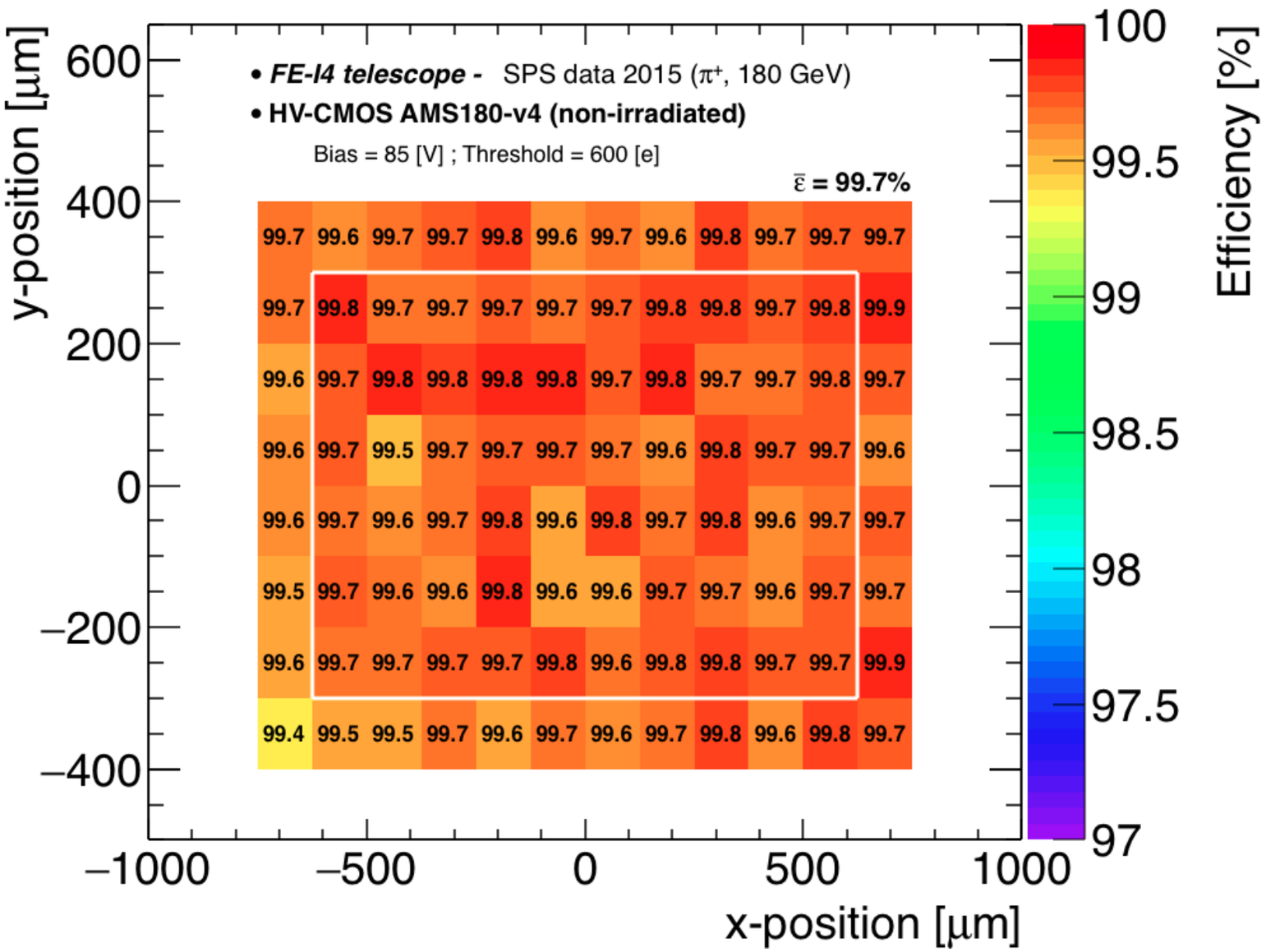
- 180 GeV pions at SPS
- 6 IBL planar pixel sensors: 250x 50 μm
- Trigger was given by the coincidence of plane 0 and 5
- Region of Interest defined - > trigger rate of ~4 kHz
- Resolution at DUT: ~8µm x 10µm
- New offline reco. software:

https://gitlab.cern.ch/unige-fei4tel/proteus



Test beam results: non-irradiated sensors

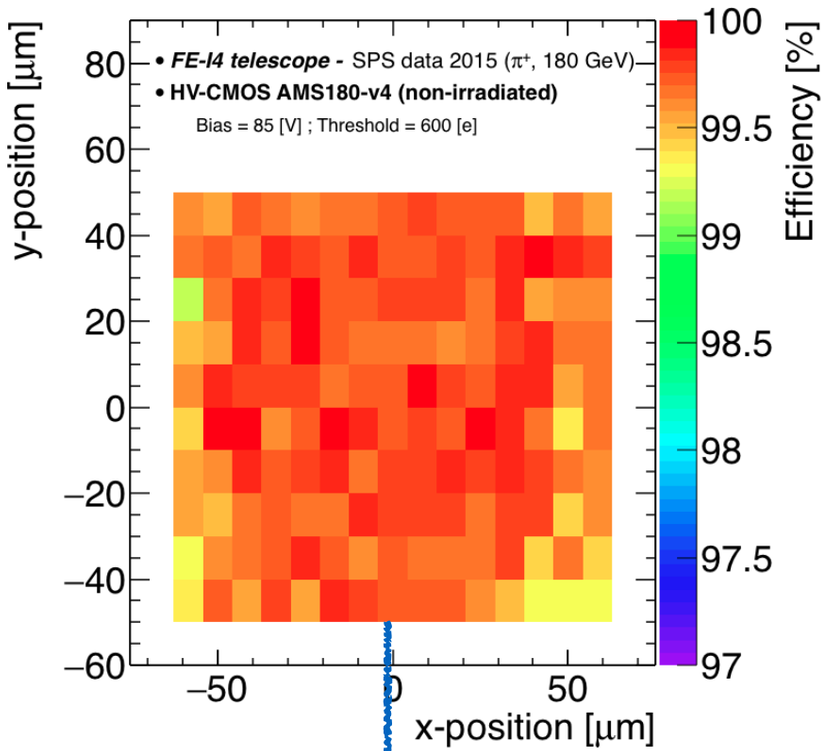
- Efficiency map of the non-irr. sensor



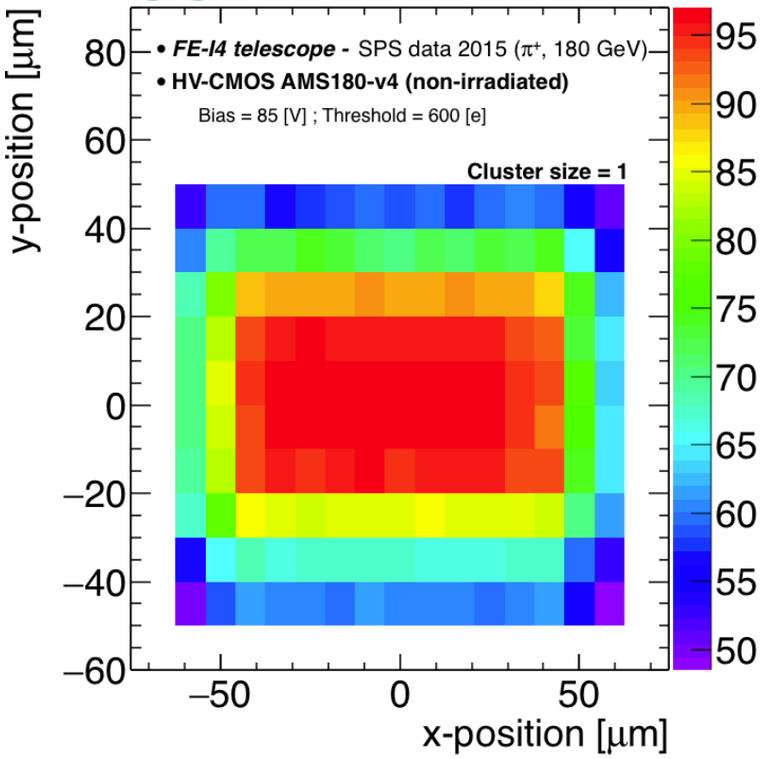
arXiv:1603.07798

Test beam results: non-irradiated sensors

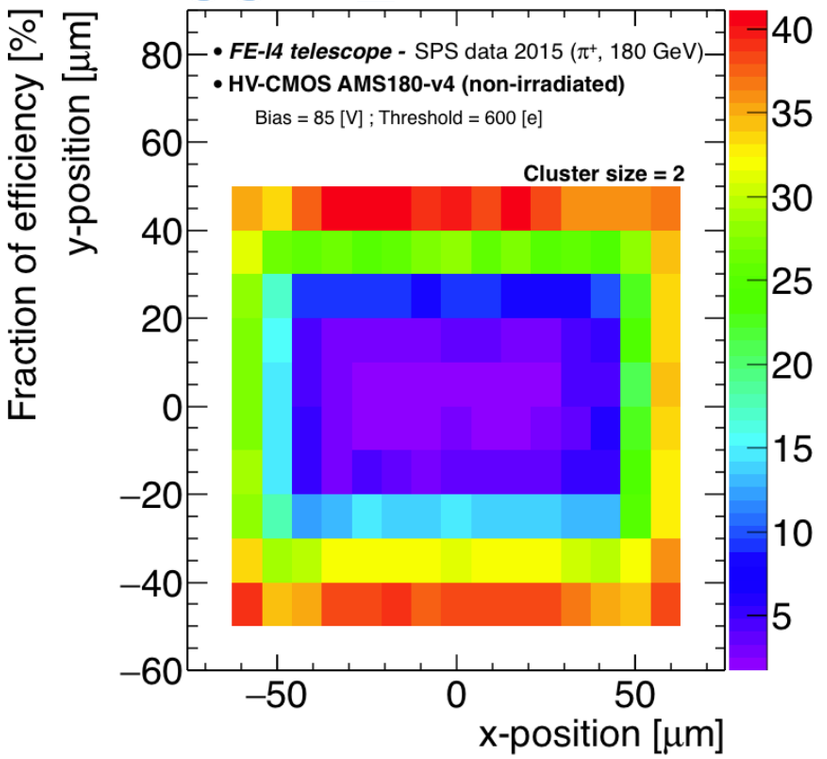
arXiv:1603.07798



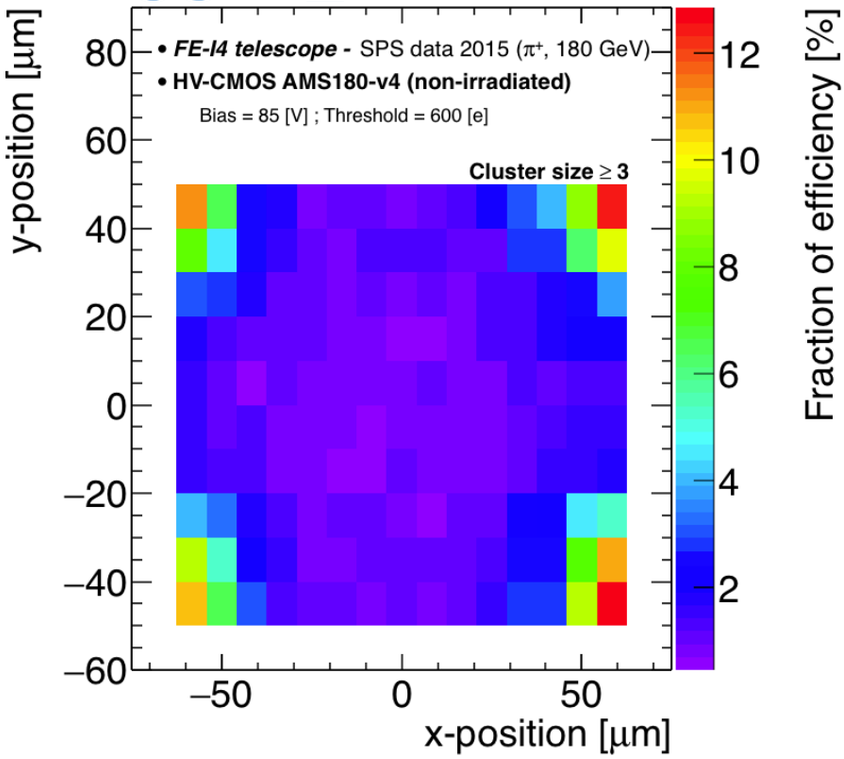
CS = 1



CS = 2

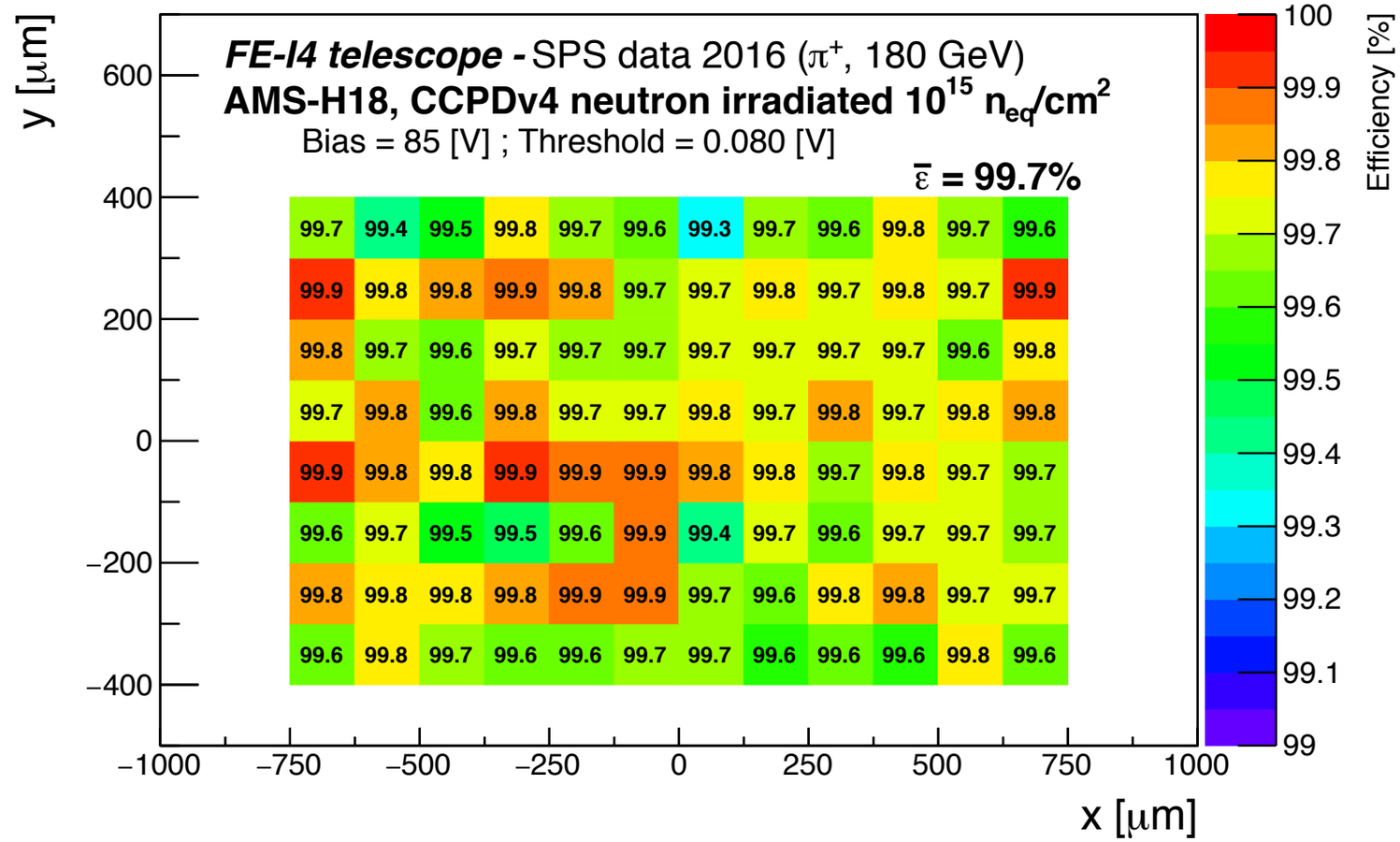


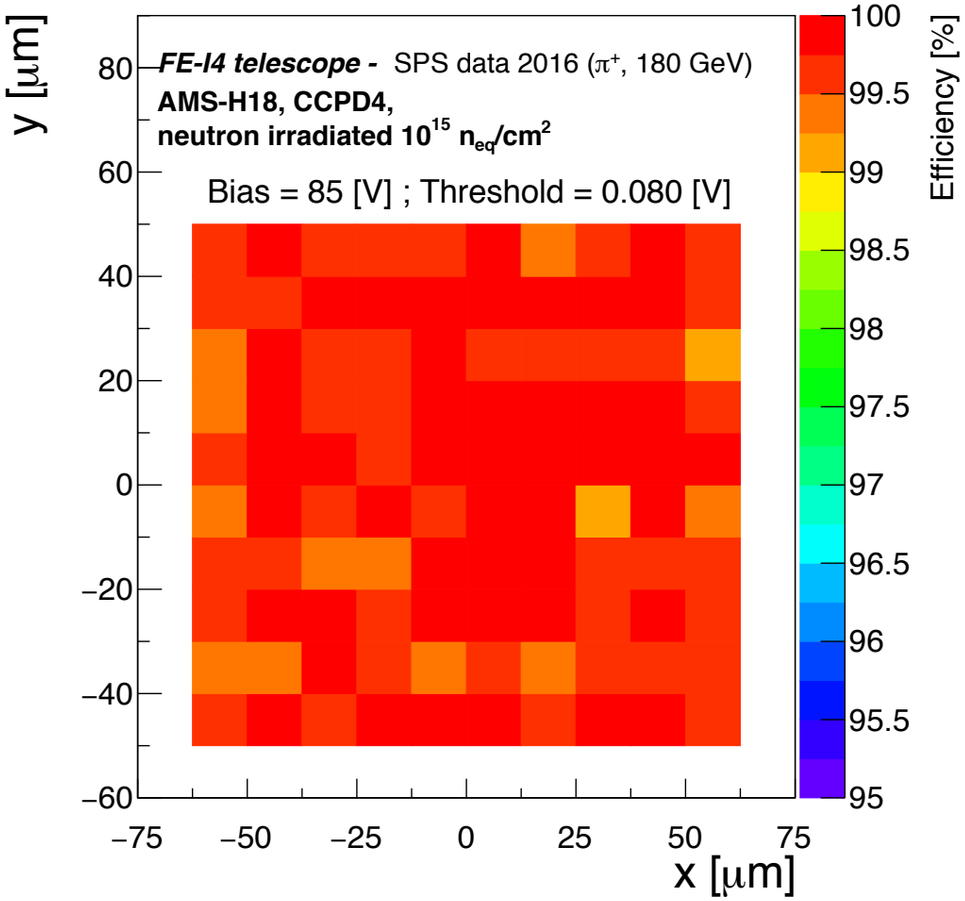
CS > 2



Test beam results irradiated

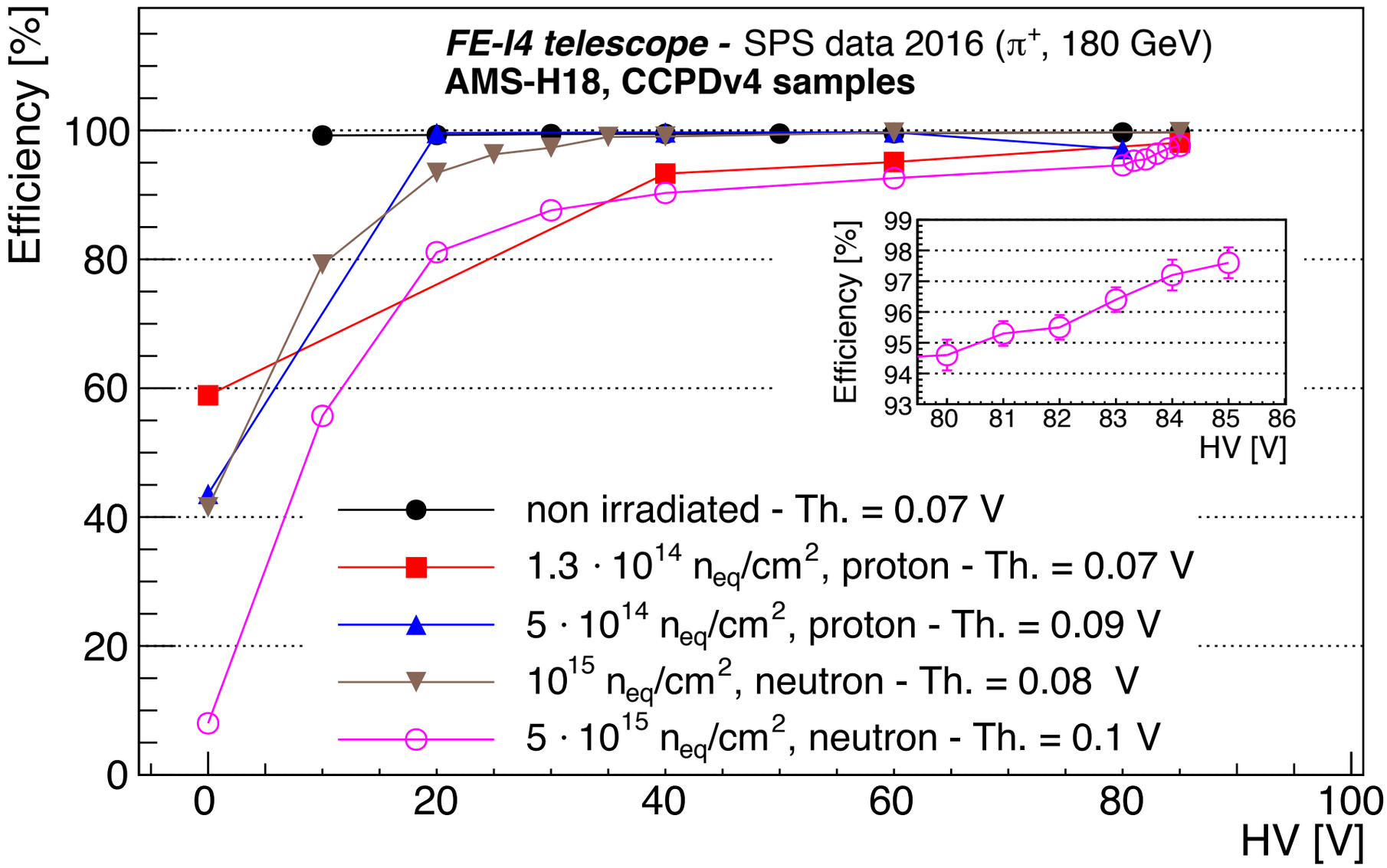
- Efficiency of the irr. (10e15 neq/cm^2) sensor



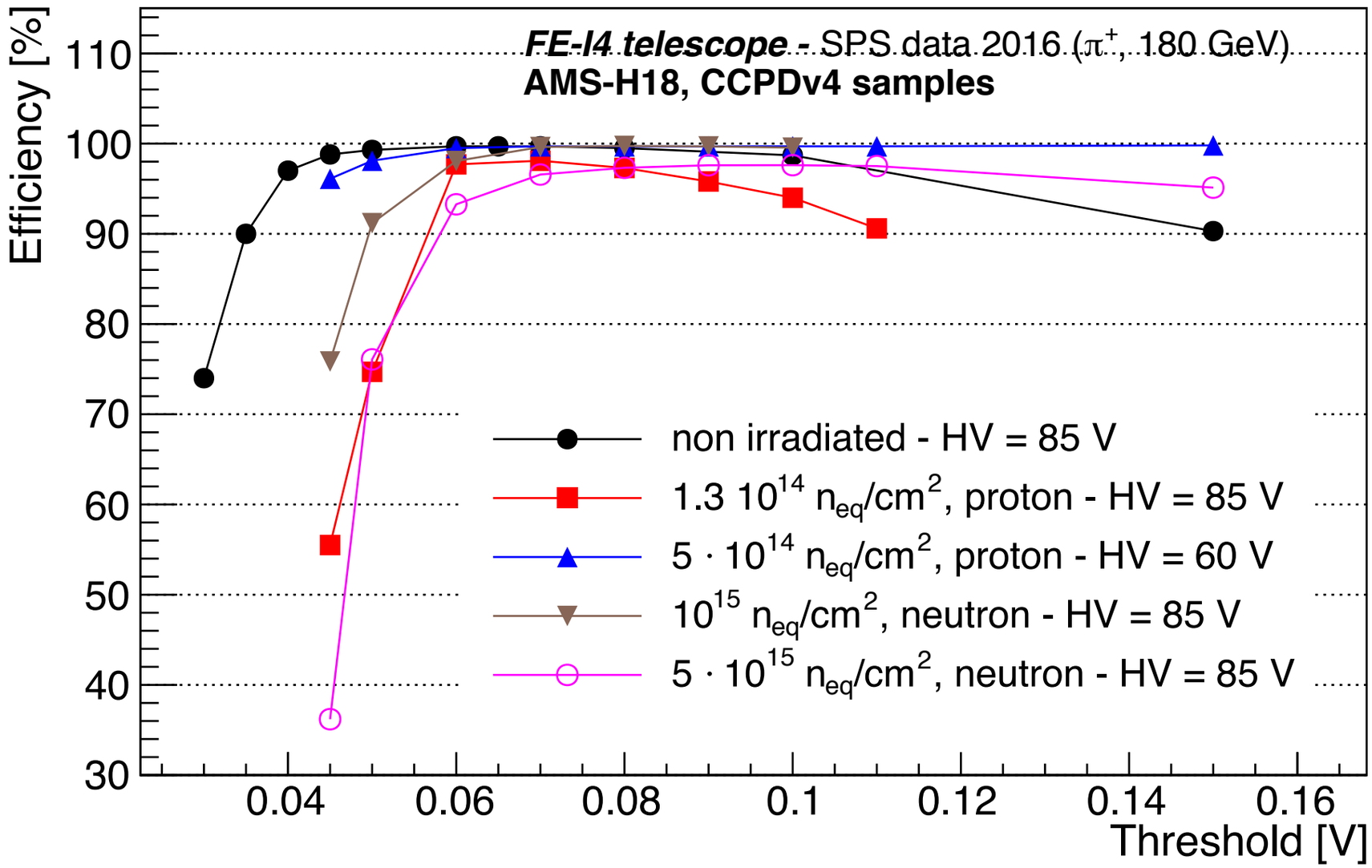


arXiv:1611.02669

Results: HV scan

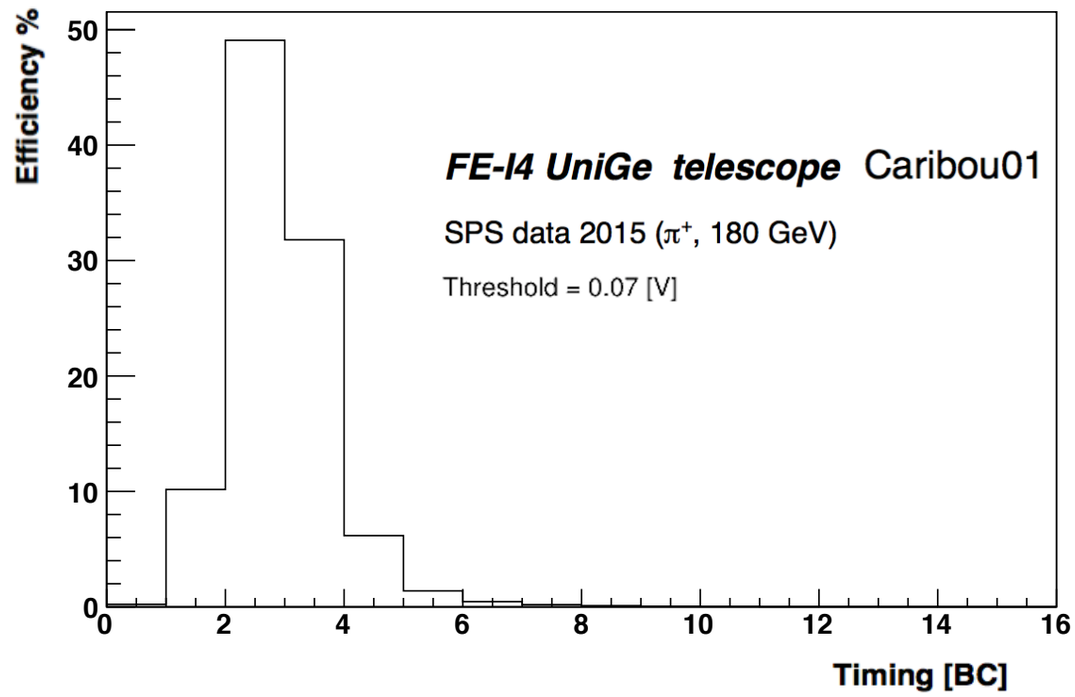


Results: Th. scan



Timing

In-Pixel efficiency contribution per BC. HV= 80 V



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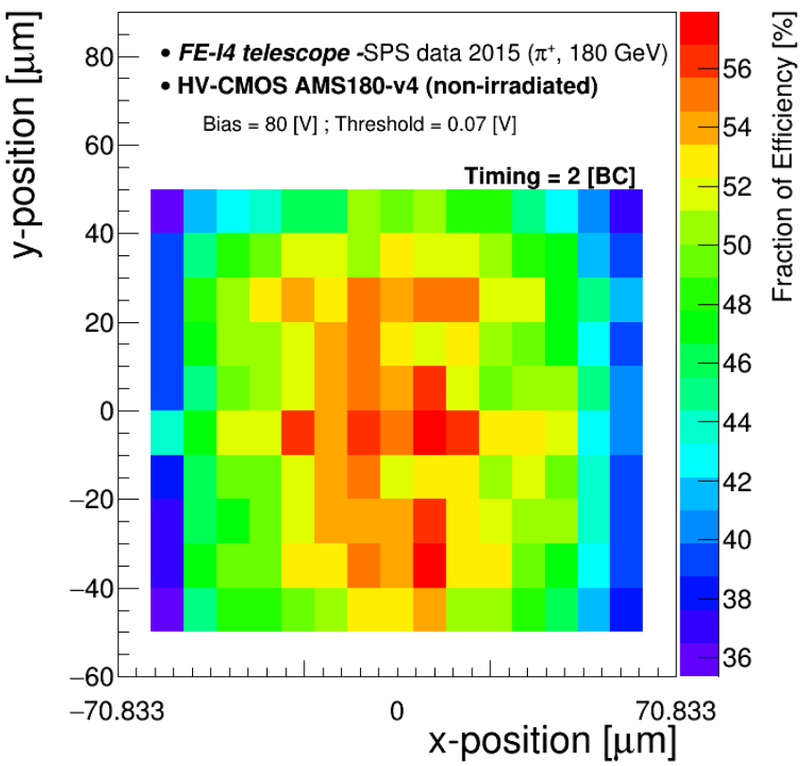

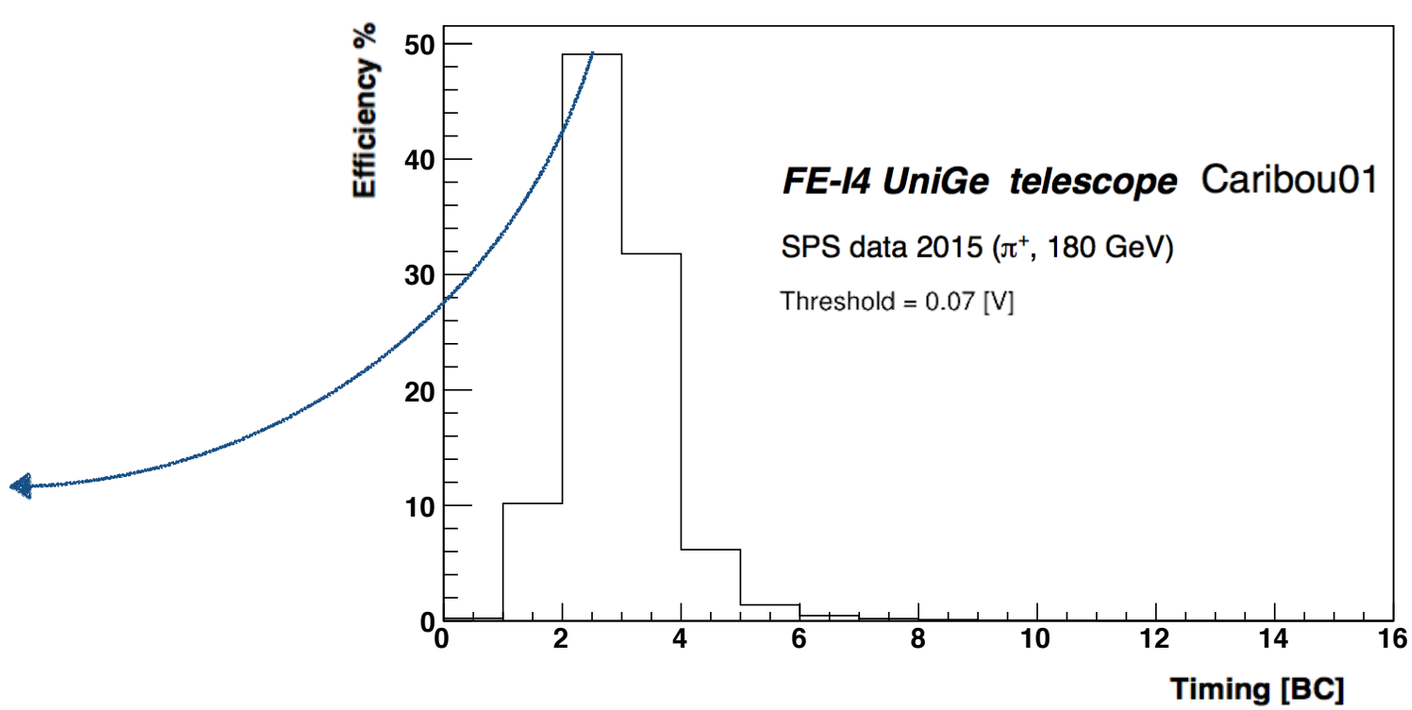

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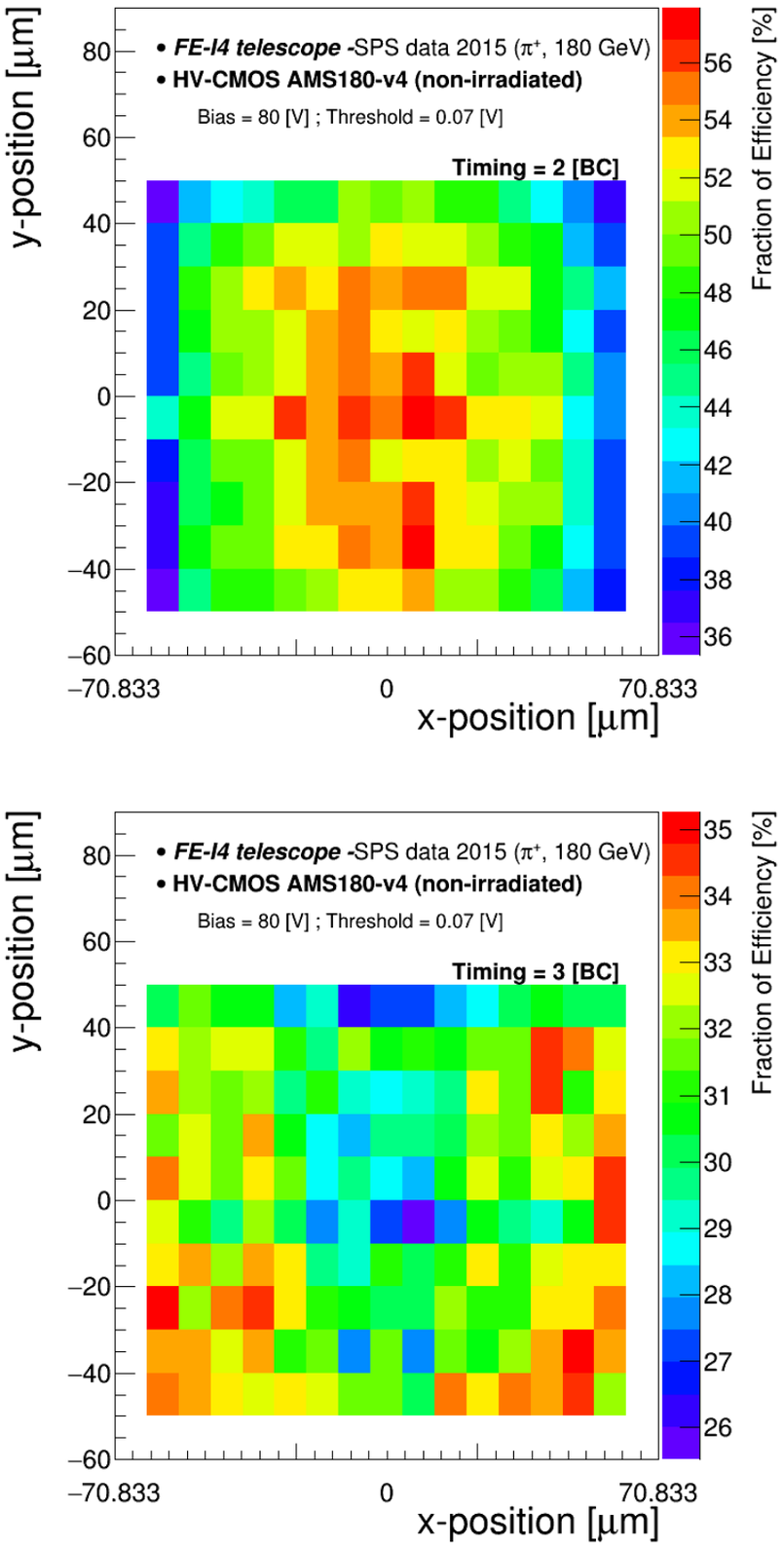

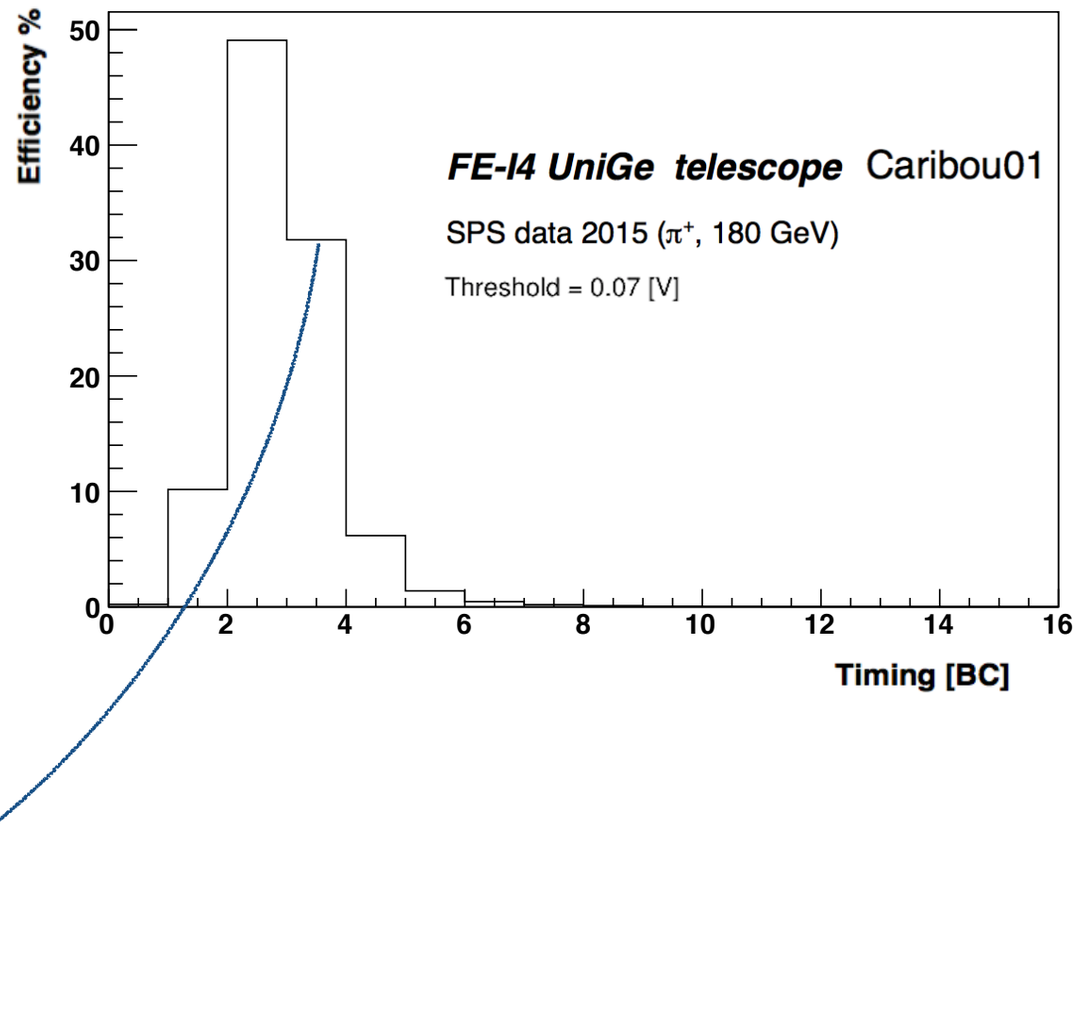

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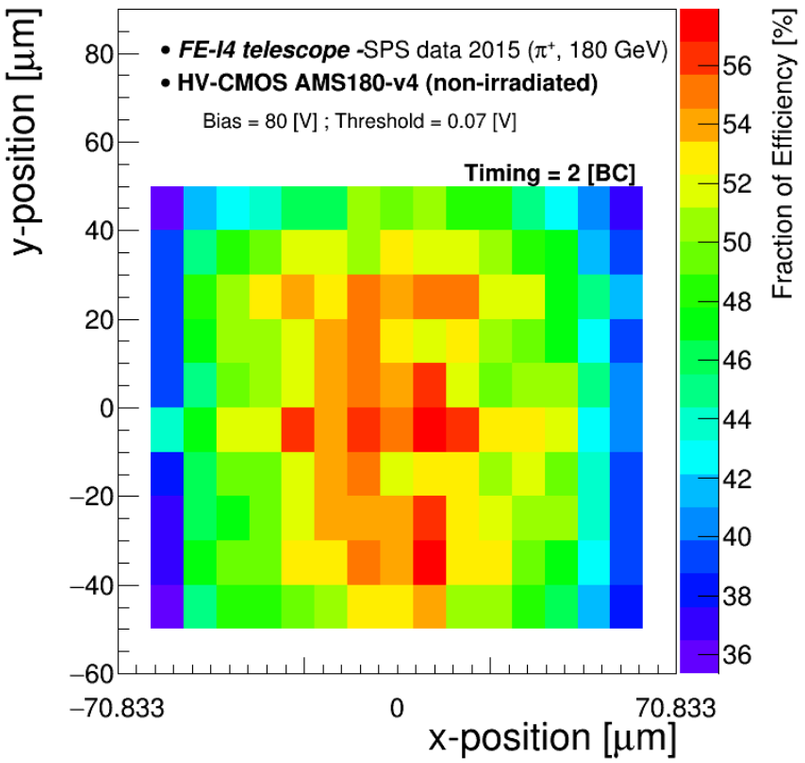

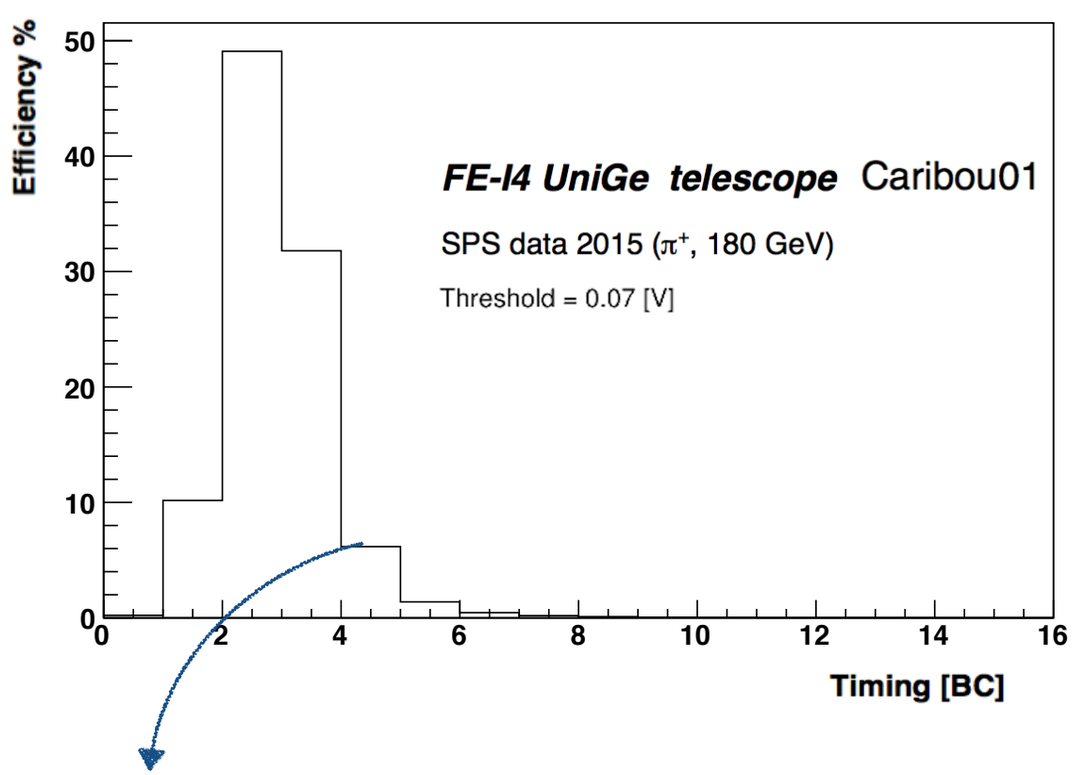

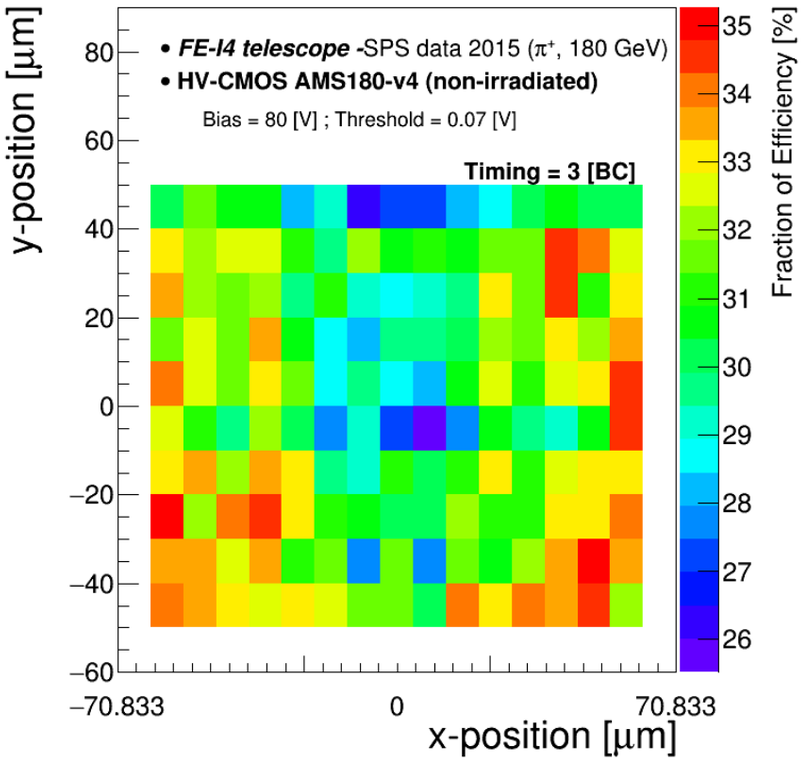

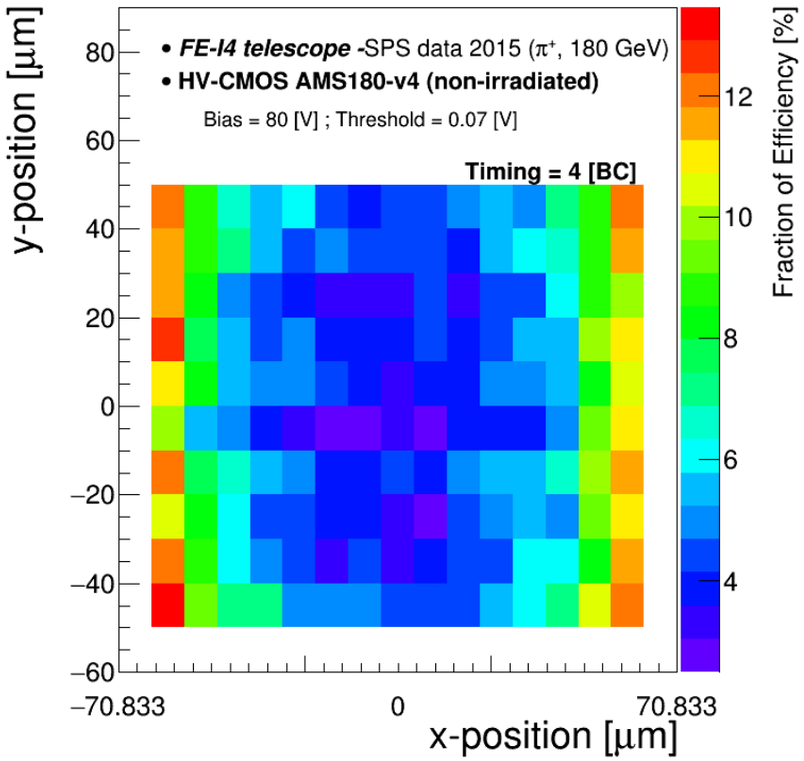

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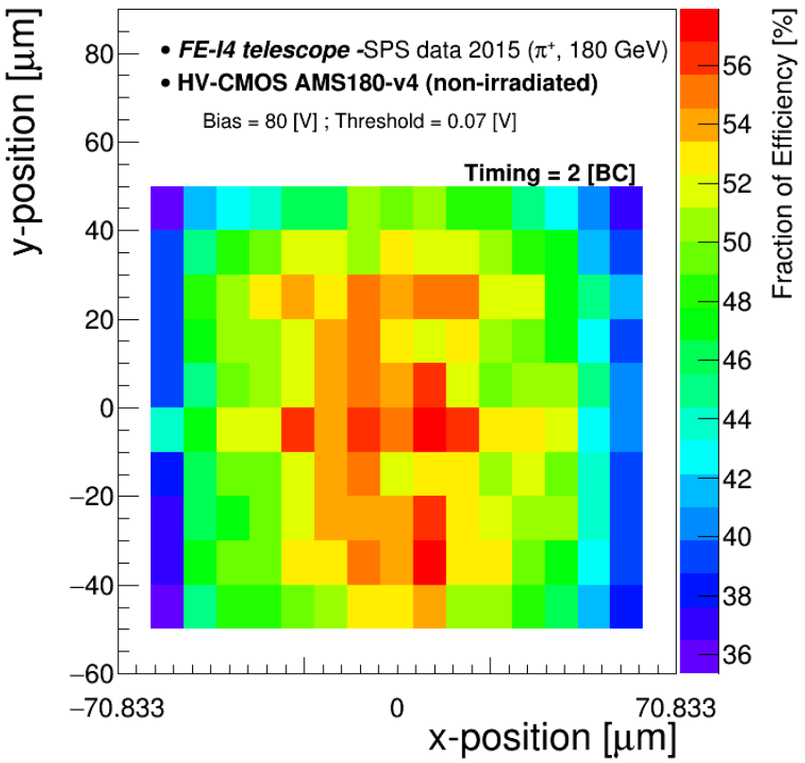
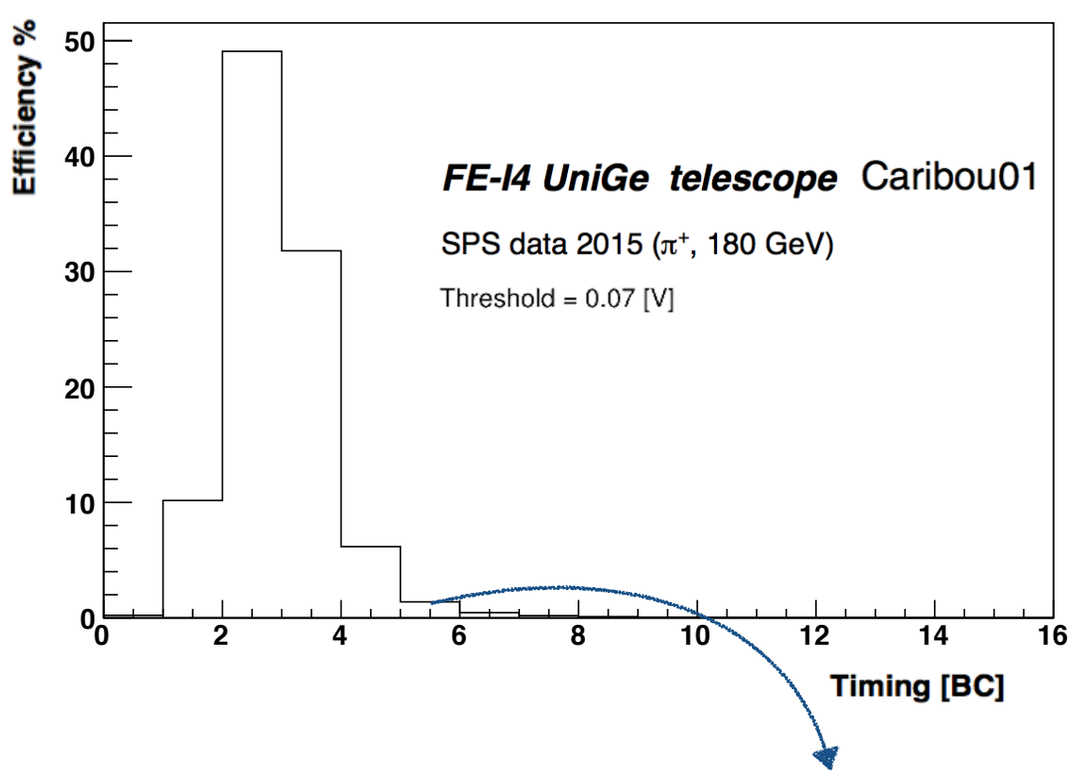
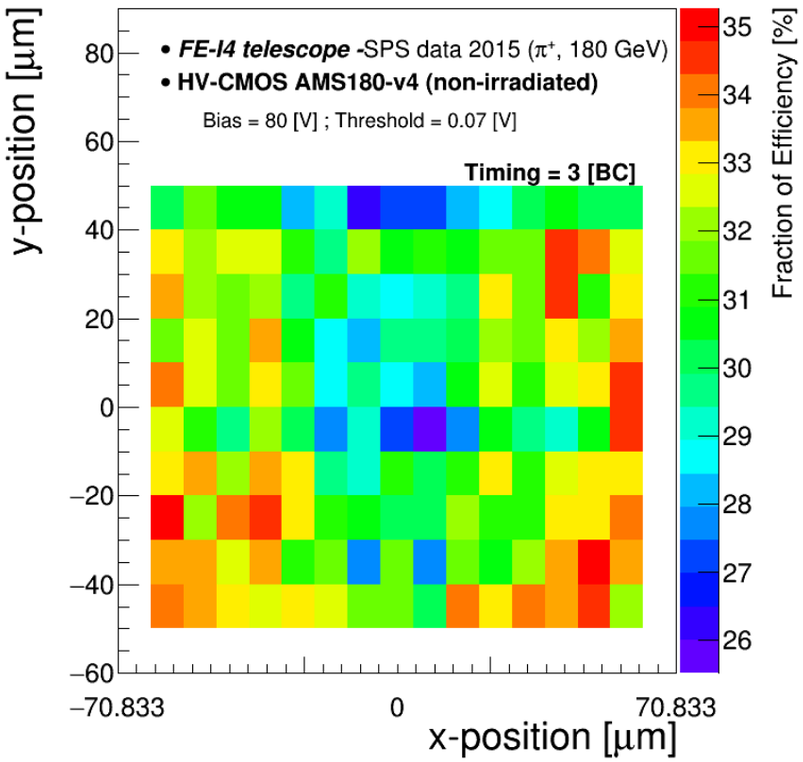
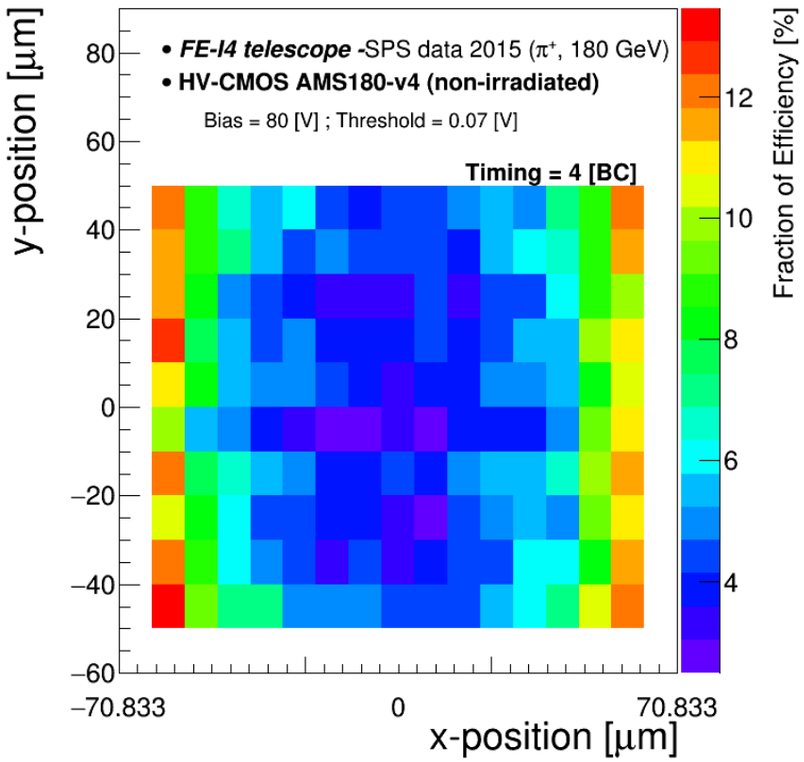
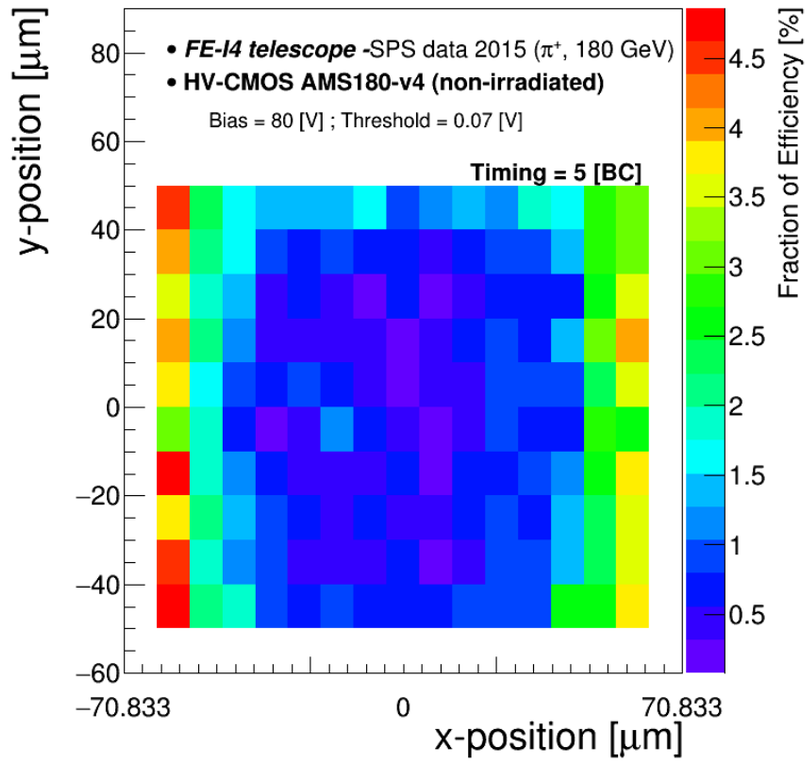






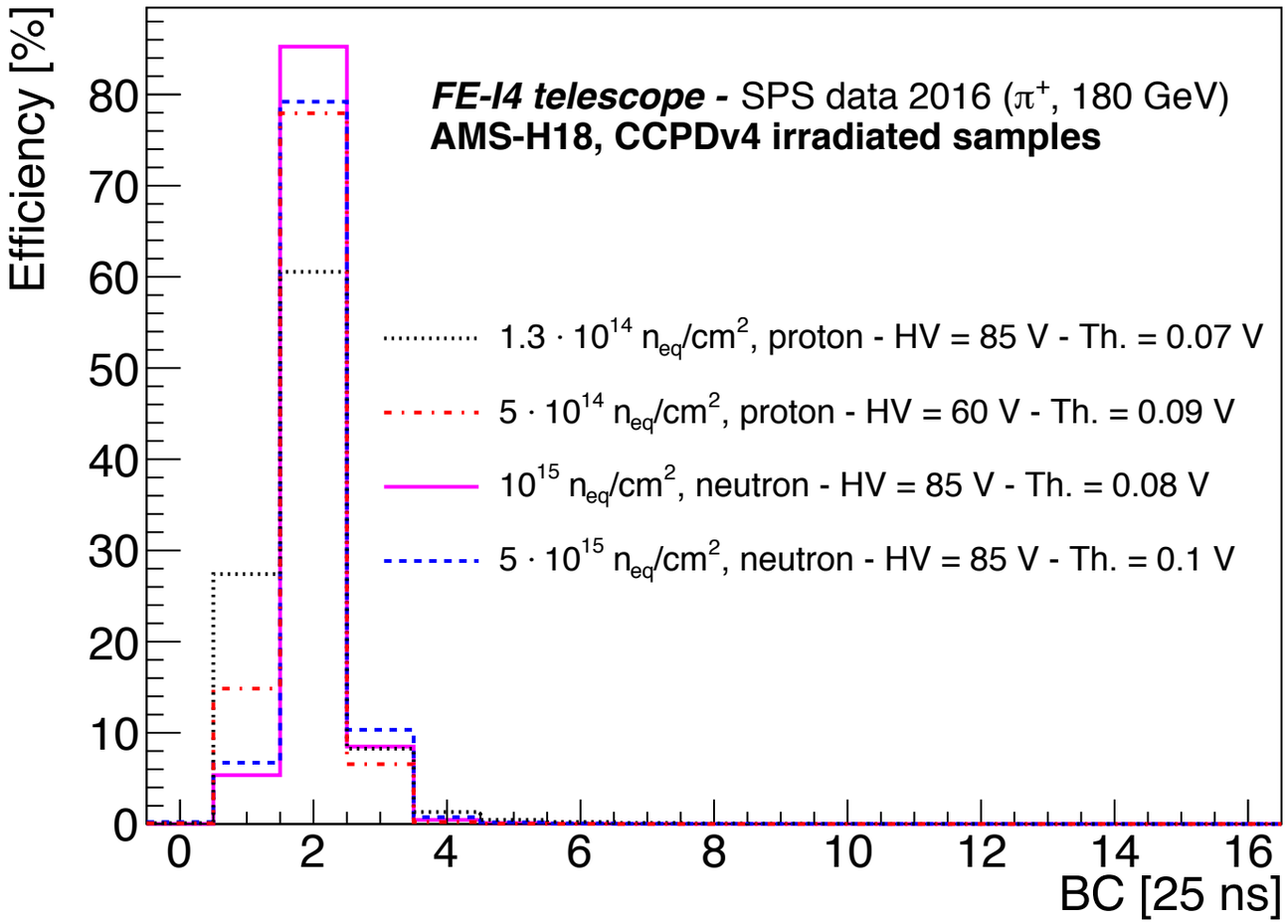


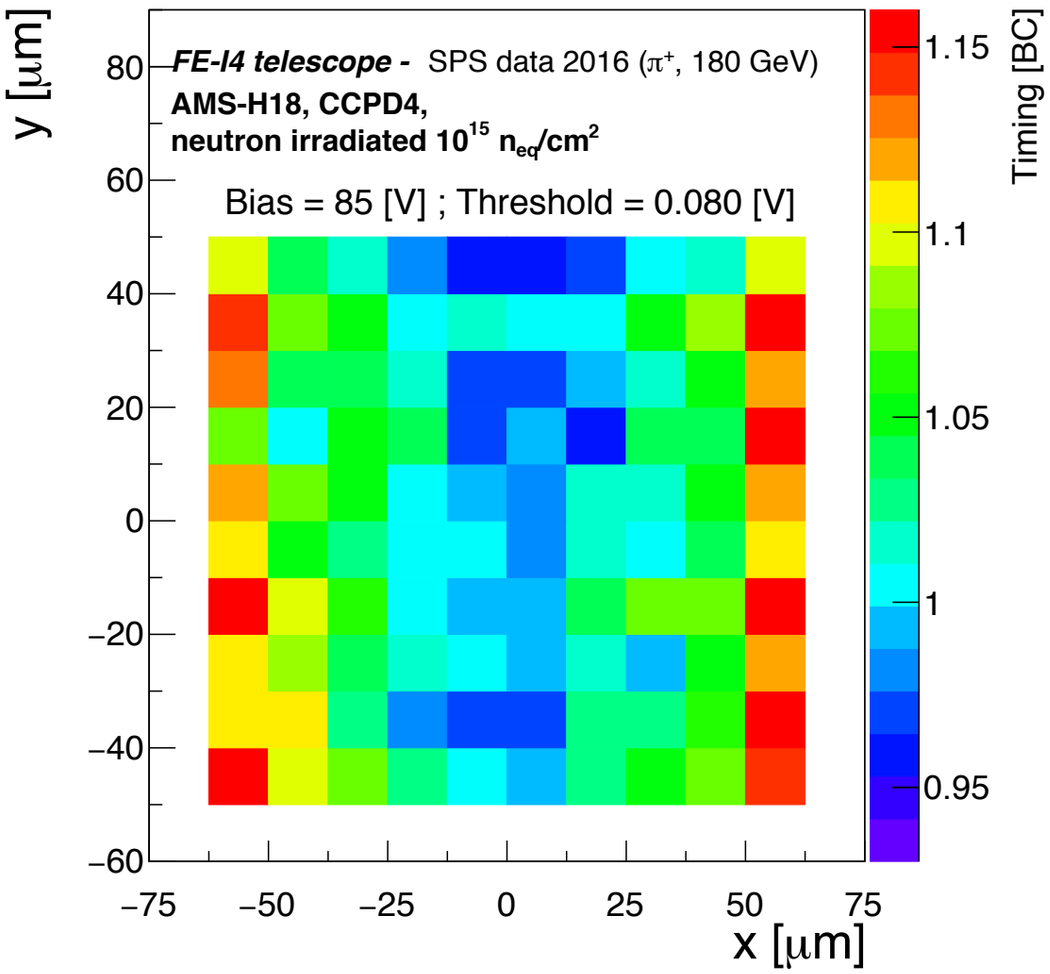


Irradiated samples: timing

- Acceptor removal mechanism enhances charge collected by drift -> fast collection!

For each bin: $\frac{\sum_{tracks} timing}{\#tracks}$





Conclusions

- HV-CMOS are possible technology for the ITK
- A DAQ system, an FEI4-based telescope and a new reco. software have been developed
- Efficiency and timing properties have been measured:
  - Result show high efficiency and promising timing response of the CCPDs
  - Acceptor removal mechanism observed in test-beam. For TCT measurement see C. Merlassino's slides and E. Zaffaroni's poster
- Higher resistivity and higher biasing voltage will improve the timing performance of the detector
- First full size demonstrator has been investigated. M. Vicente, C. Merlassino's slides and E. Zaffaroni's poster

Useful links

1. A new DAQ system - Development of a modular test system for the silicon sensor R&D of the ATLAS Upgrade": JINST 12 P01008 (2017)

2. An FEI4 Telescope has been built and commissioned - The FE-I4 Telescope for particle tracking in testbeam experiments": JINST 11 P07003 (2016)

3. Test-Beam results from the CERN SPS

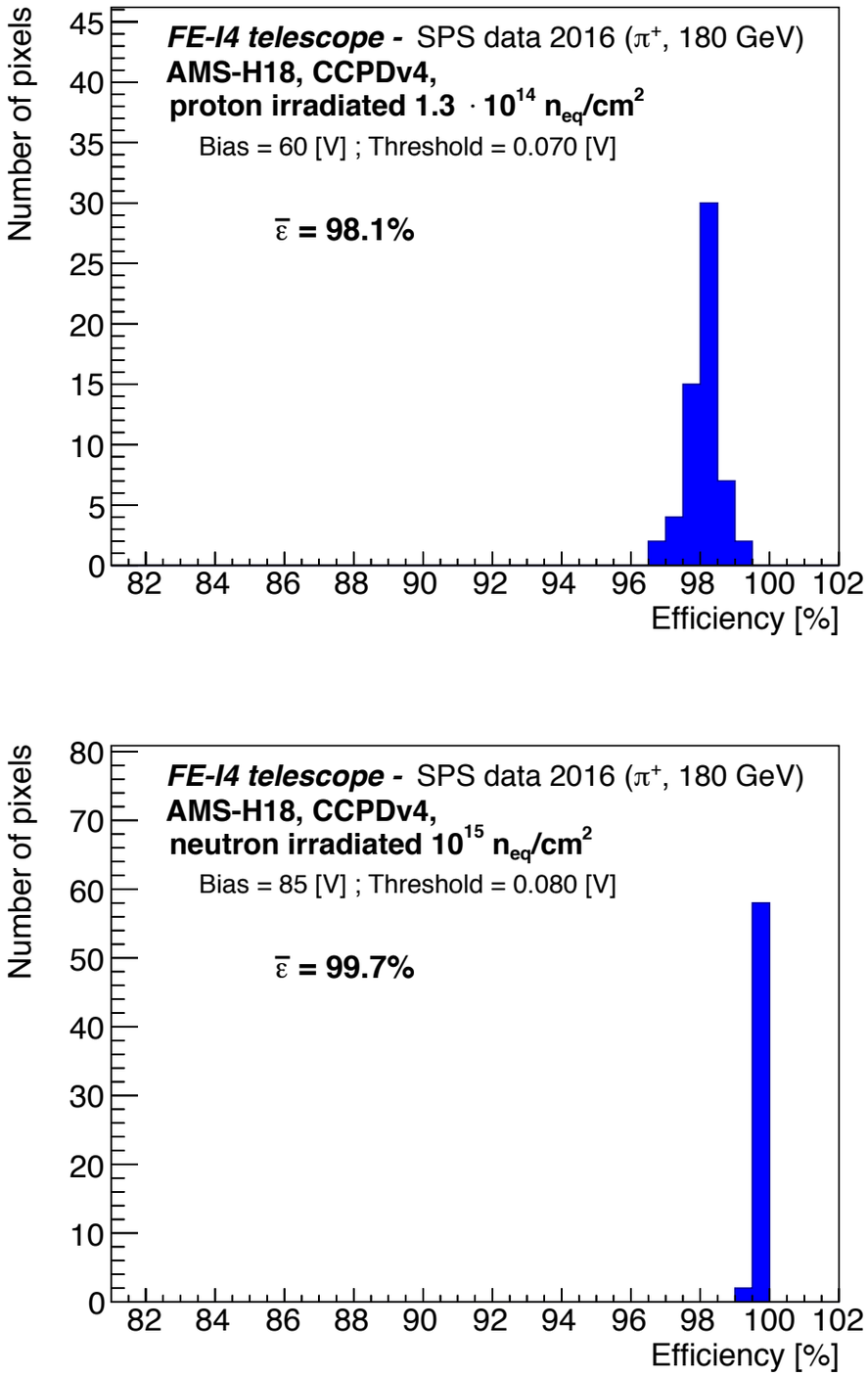
Results of the 2015 testbeam of a 180 nm AMS High-Voltage CMOS sensor prototype": JINST 11 P07019 (2016)

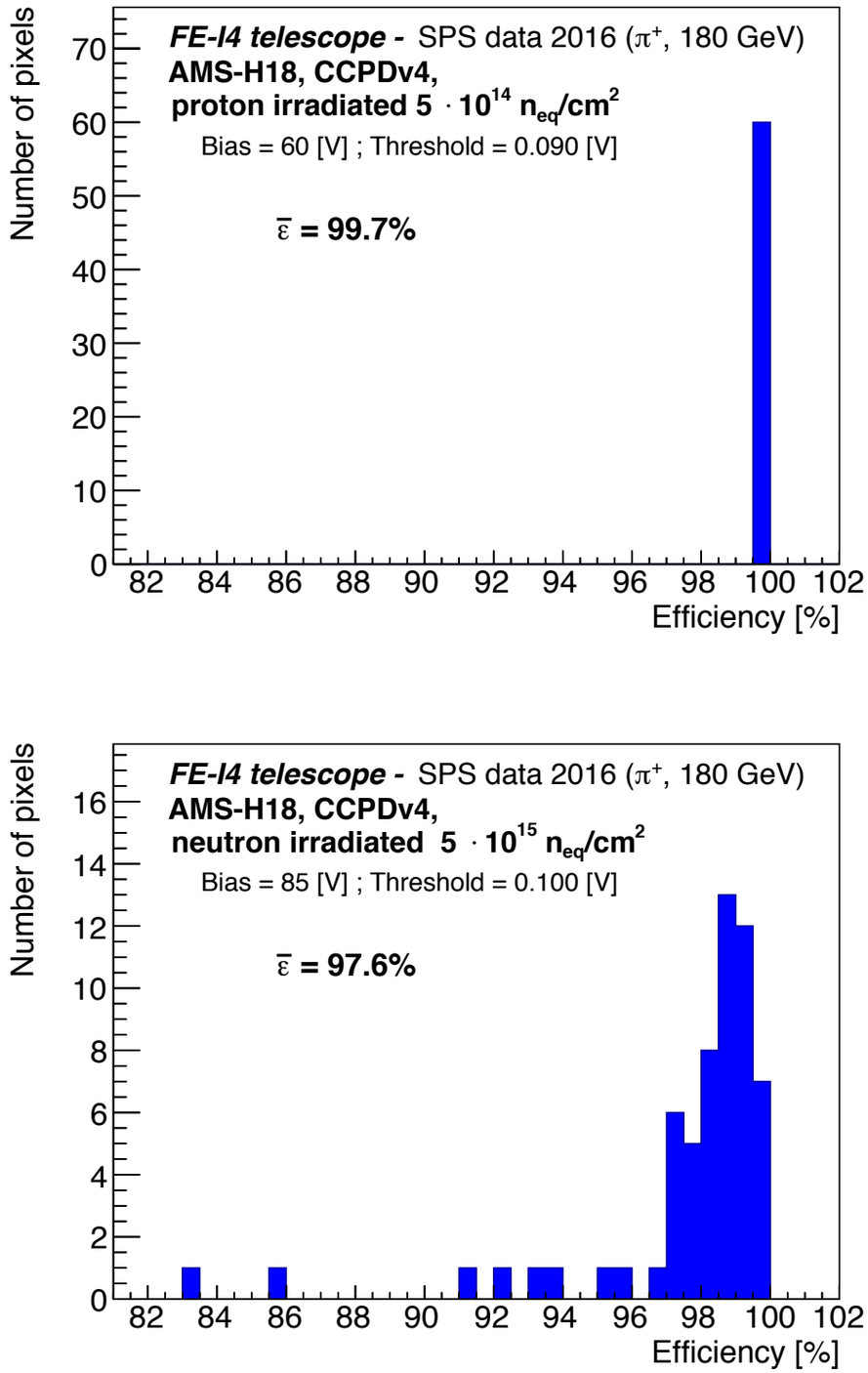
Testbeam results of irradiated ams H18 HV-CMOS pixel sensor prototypes - arXiv:1611.02669 (2017)

Backup

Irradiated samples: results

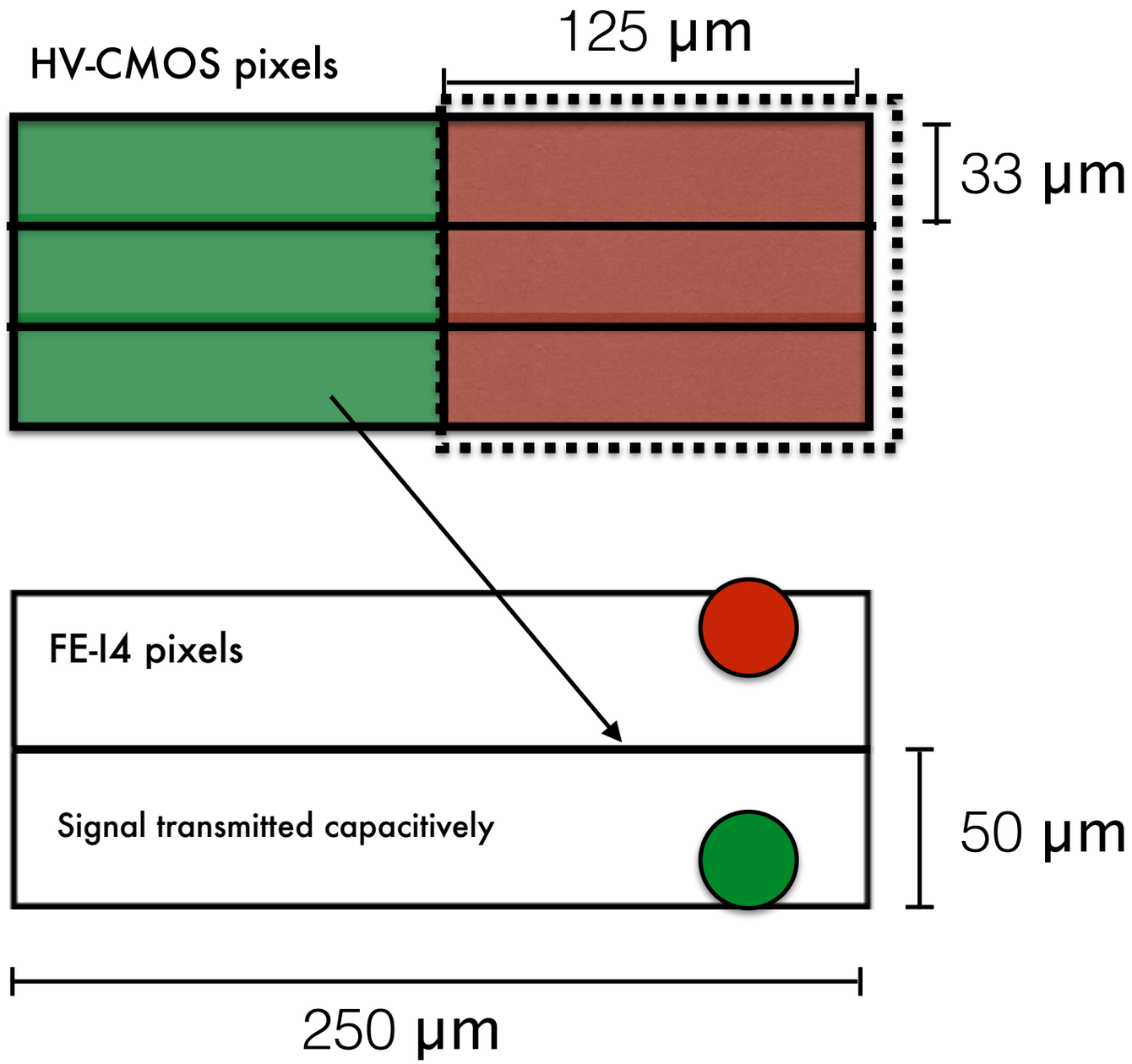
arXiv:1611.02669





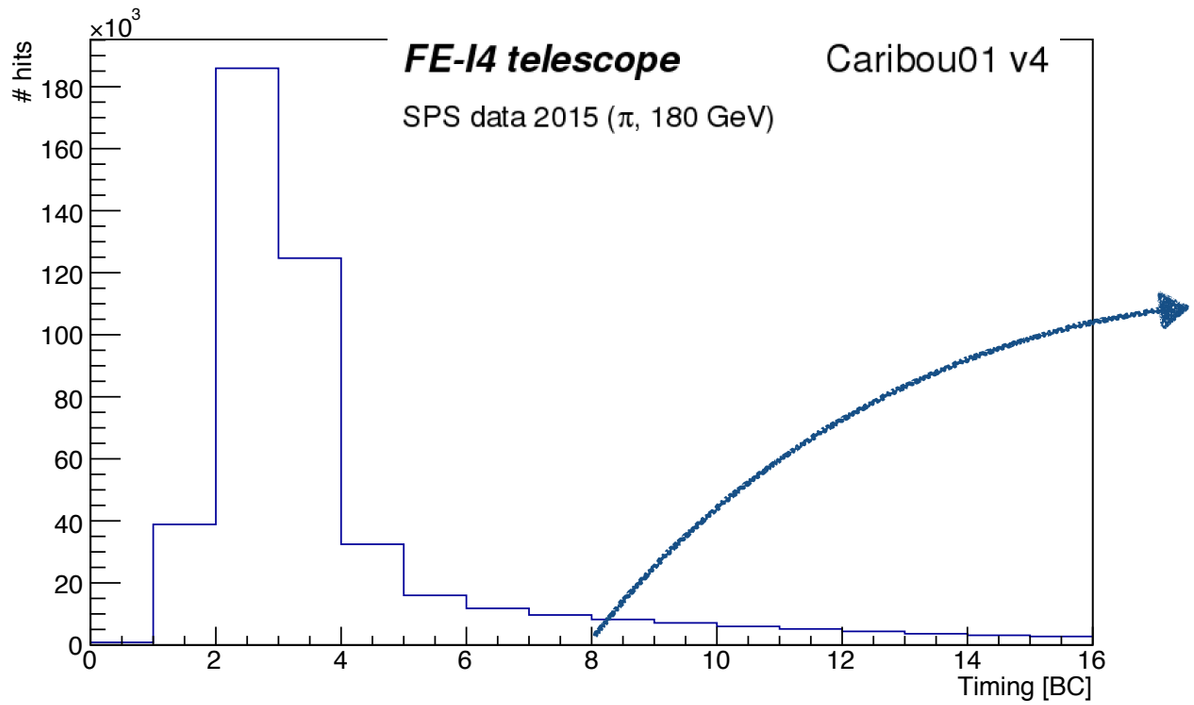
HV-CMOS pixels connection to FE-I4

- HV-CMOS pixel size:
  125 x 33 μm
- FE-I4 pixel size:
  250x 50 μm
- 3 HV-CMOS sub-pixels connected to 1 FE-I4 pixel
- In reconstruction we define a virtual pixel of 100 x 125 μm containing 3 HV-CMOS sub-pixels



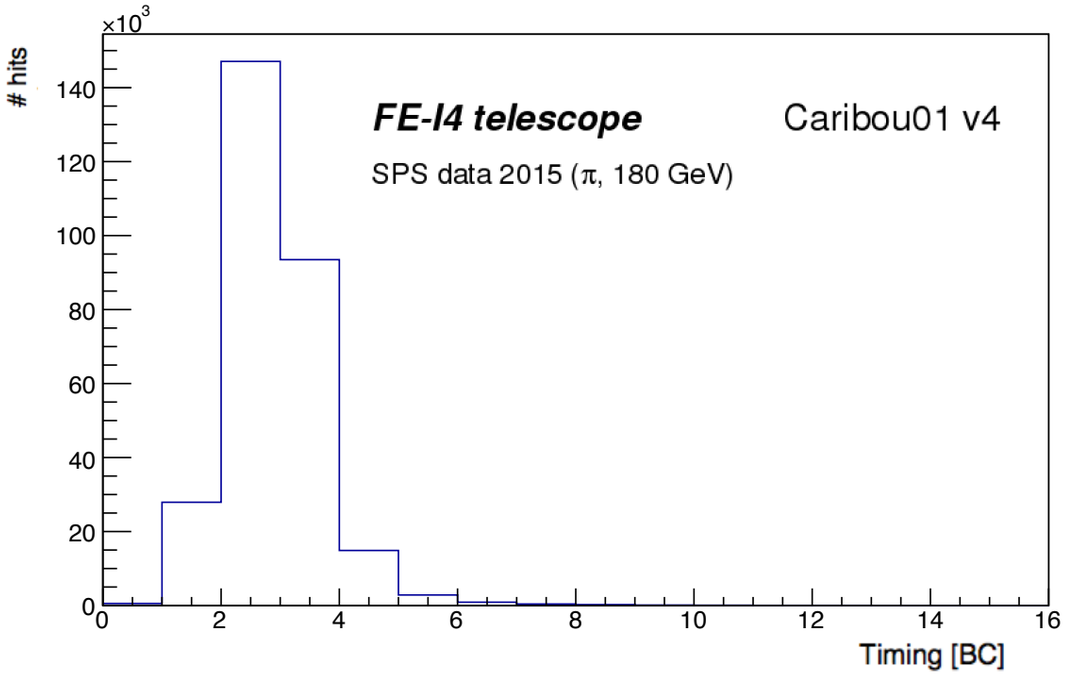
Timing Studies, distribution for matched clusters

- Scan over 16 BC in clock bin of 25 ns around trigger

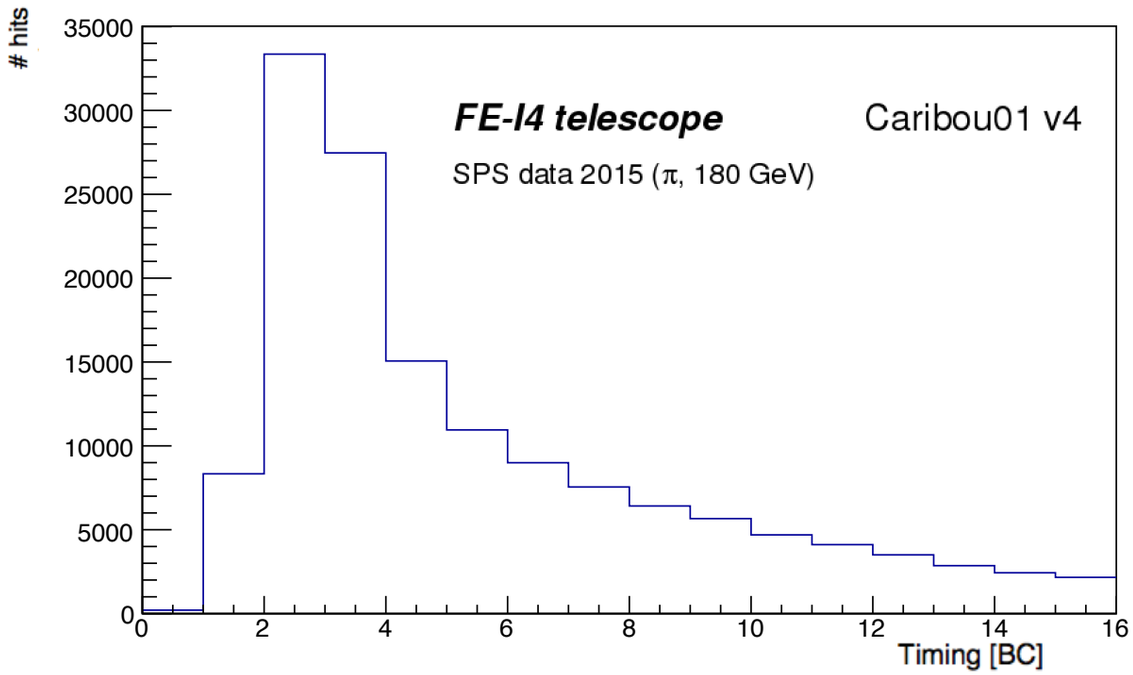


- Long tail arises from C.S. > 1

C.S.=1

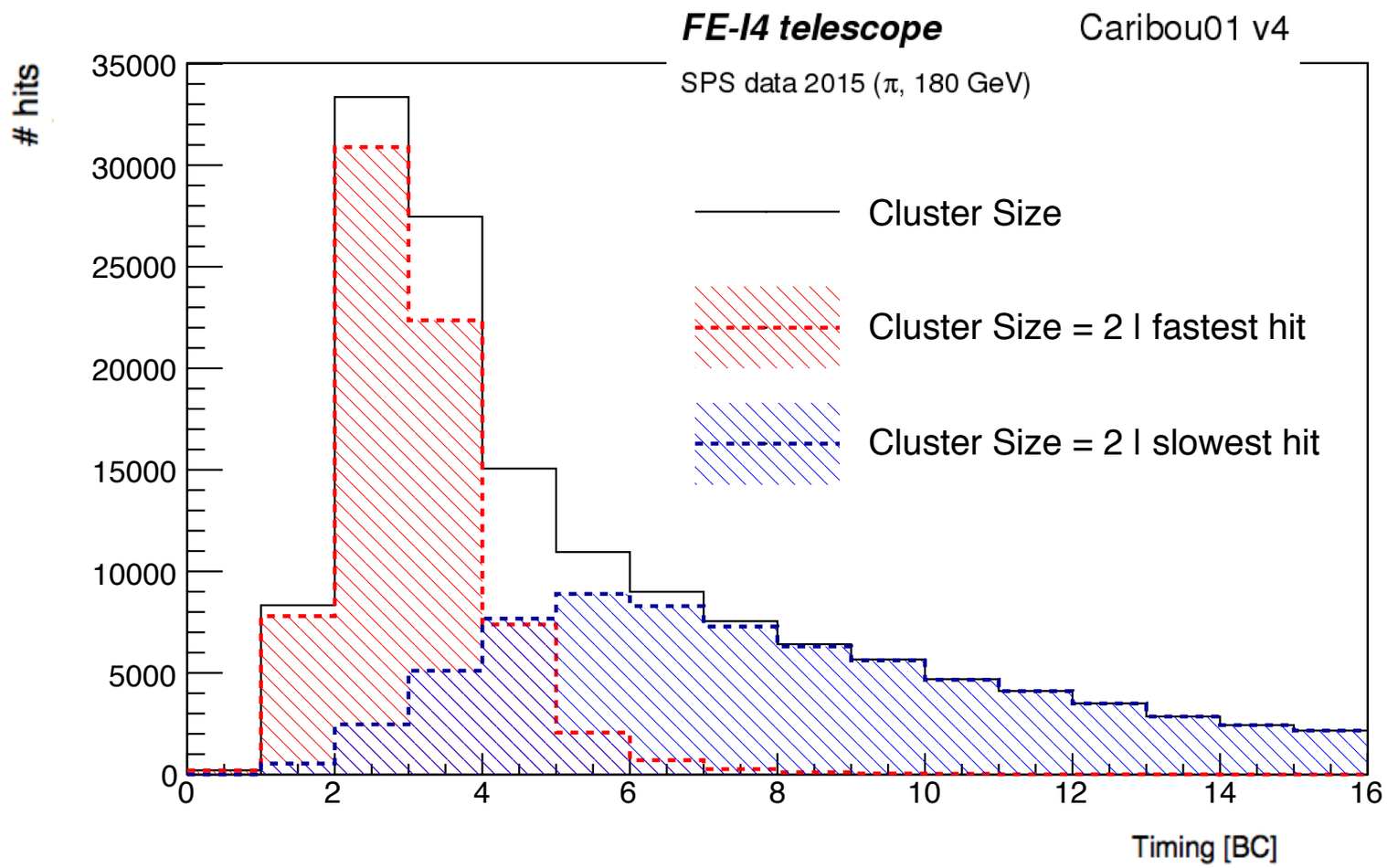


C.S.=2



Timing Studies

- Selecting the fastest hit in cluster the tail is strongly reduced



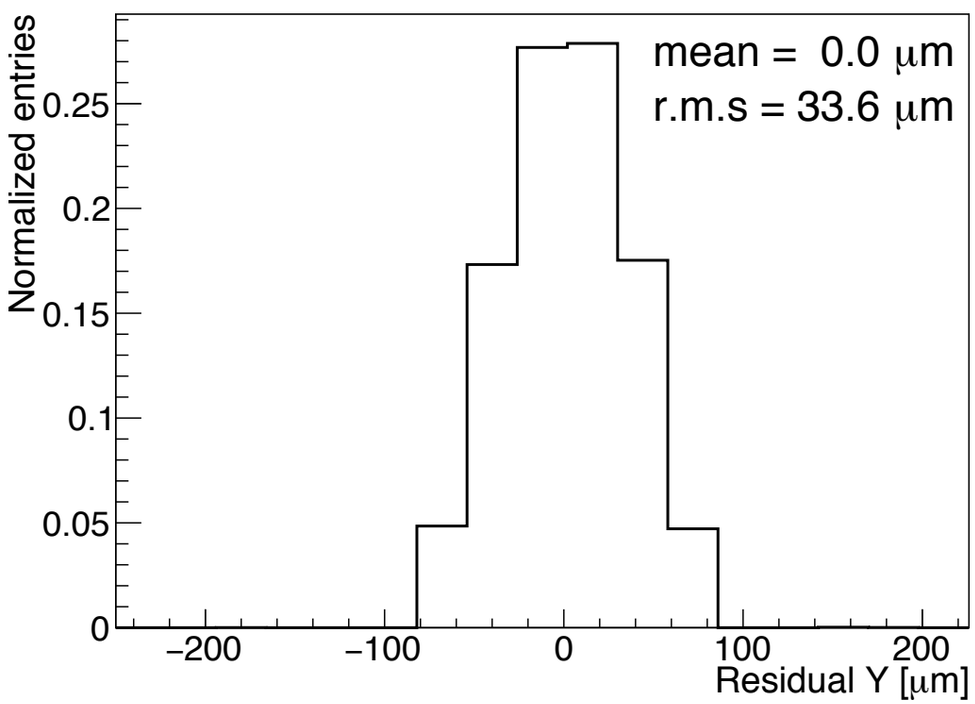
- In the following I will show results taking fastest hit in clusters

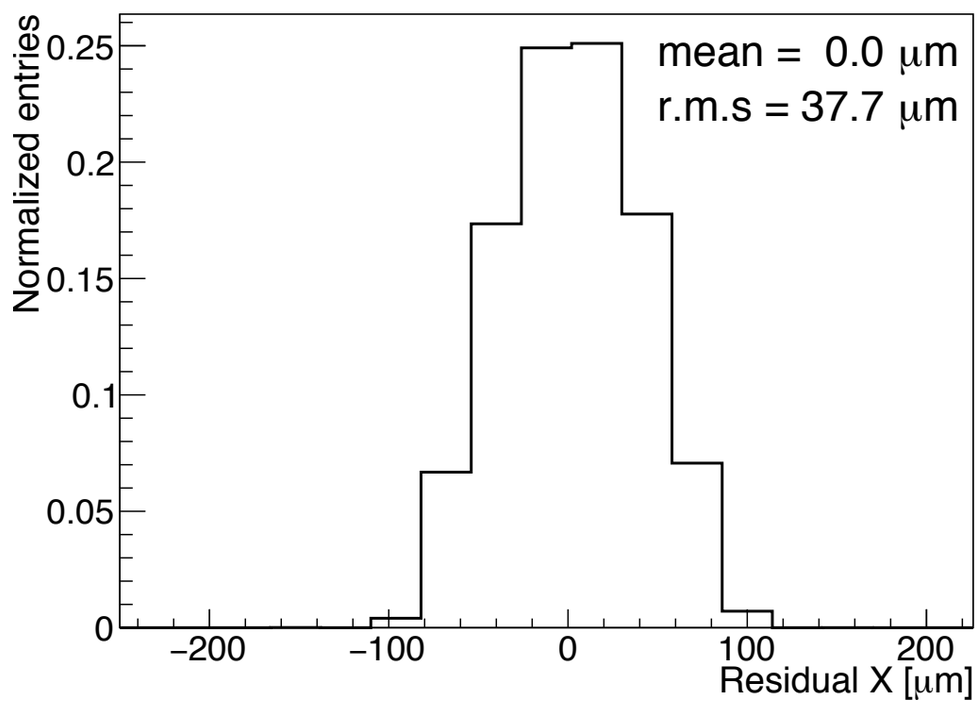
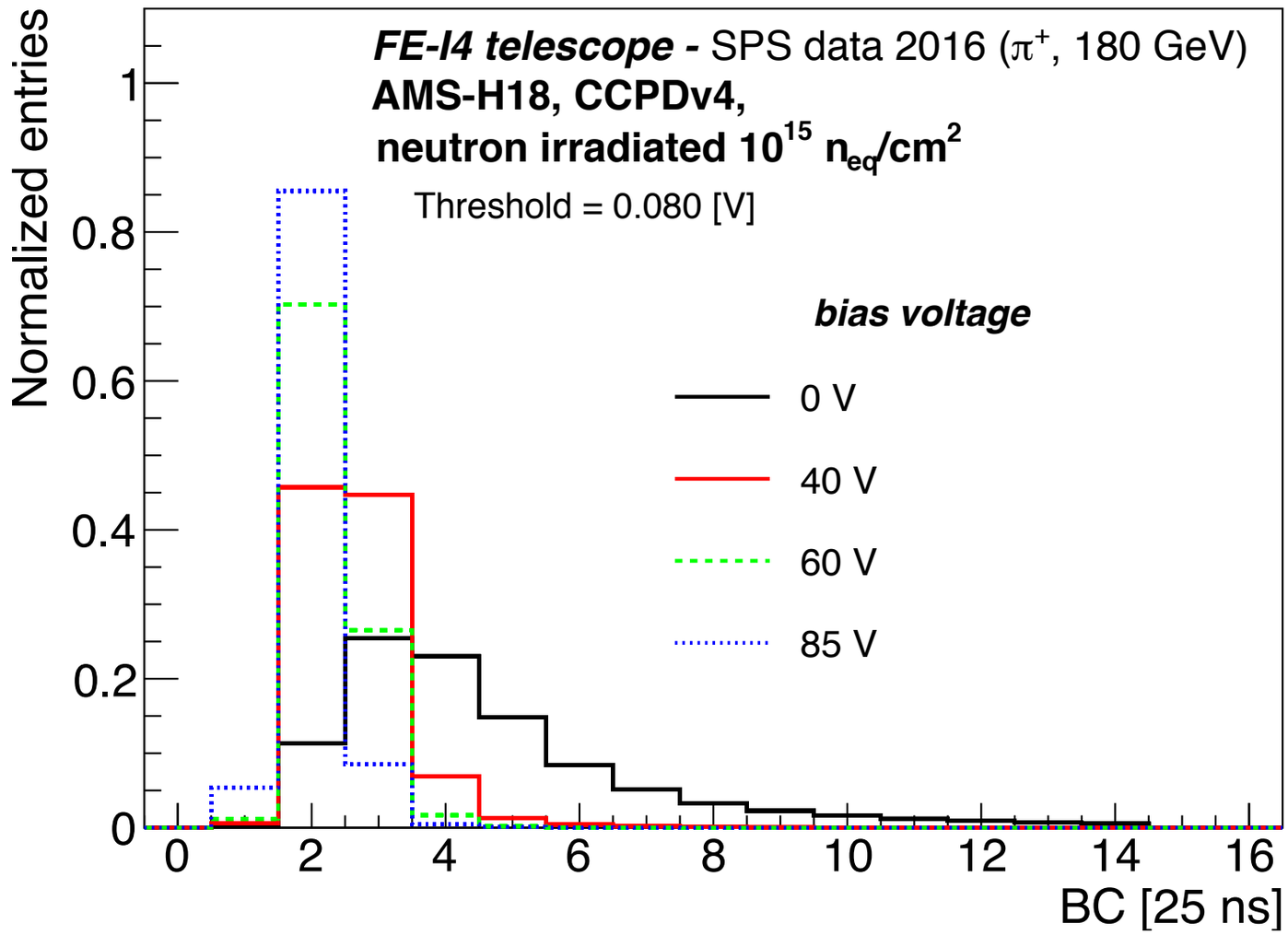
CS distribution

Table 1. Cluster size fractions for different fluences.

Fluence [n_{eq}/cm^2]	0	$1.3 \cdot 10^{14}$	$5 \cdot 10^{14}$	$1 \cdot 10^{15}$	$5 \cdot 10^{15}$
CS = 1	0.783	0.970	0.958	0.978	0.961
CS = 2	0.196	0.028	0.038	0.020	0.034
CS $\geq$ 3	0.020	0.002	0.004	0.002	0.004

Irradiated samples: results





Irradiated samples: results