EP R&D
pixel-detector beam tests 2024

EATM test-beam feedback meeting
November 12th, 2024

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on behalf of the EP-DT-TP test-beam team

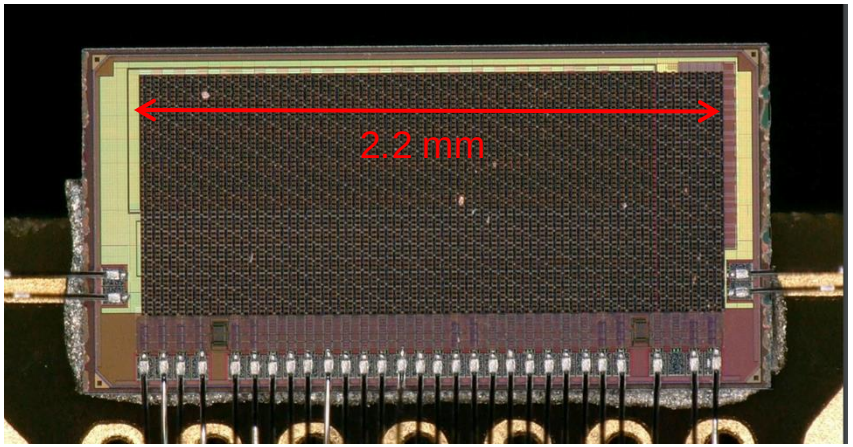
EP R&D 2024 pixel-detector beam tests

- **Silicon pixel detector R&D** for future high-energy collider precision experiments: Thin sensors (**20-150 µm**), Small pixels (>~ **10 x 10 µm²**), precise timing (**<1 ns**)
- Focus on **Higgs-factory vertex + tracking-detector** requirements / **generic R&D**
- Additional beam times linked to EP R&D that take place within approved experiments (e.g. LHCb Velo, ALICE ITS3) are not covered here

- 2024 measurements focused on characterisation of **H2M technology demonstrator**:
  - **65 nm** modified CMOS imaging process for monolithic sensors
  - Measurement of hit **position** and **time**
  - **64x16** Pixels, pitch: **35x35 µm²**,
  - Various samples with thicknesses from **20-50 µm**
  - **Rotation scans** to investigate charge-collection properties vs. depth

DUT active-matrix size only **1.25 mm²**
➢ Need **small beams** and **high rates**

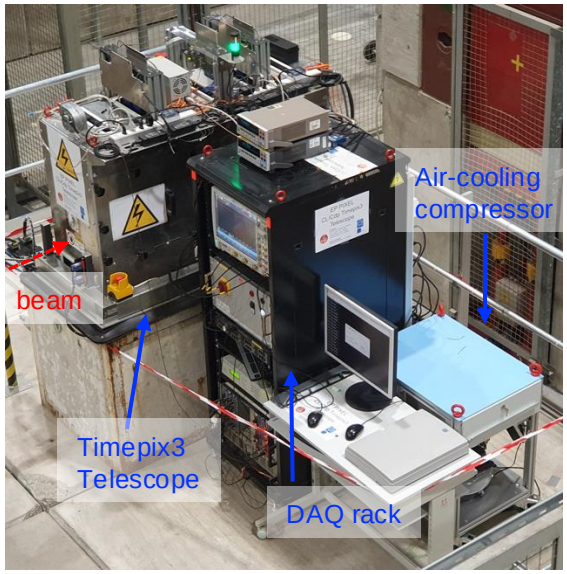
H2M sensor



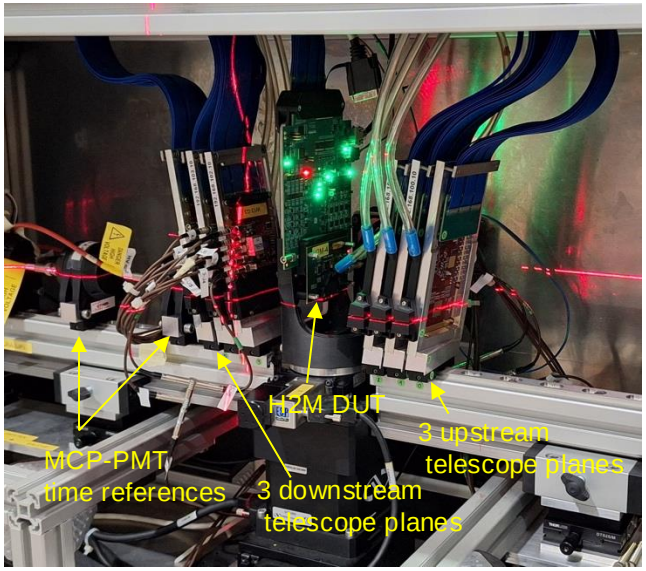
Beam telescope setup in H6B (PPE156)

- **Timepix3 based 7-planes telescope**:
  - **Self-contained** permanent setup at the **end of H6B**
    → no external services needed, except stable power and network
  - **<~2 µm** spatial resolution, **1 ns** time resolution for tracks on DUT, MCP-PMT **timing layer <~10 ps**
  - Can take rates up to **~80M hits/s**
  - **Remote-controlled telescope positioning** in horizontal/vertical direction
    → can follow changes of beam position (not possible for the other setups)
  - Grafana **monitoring** of DAQ status and environmental conditions

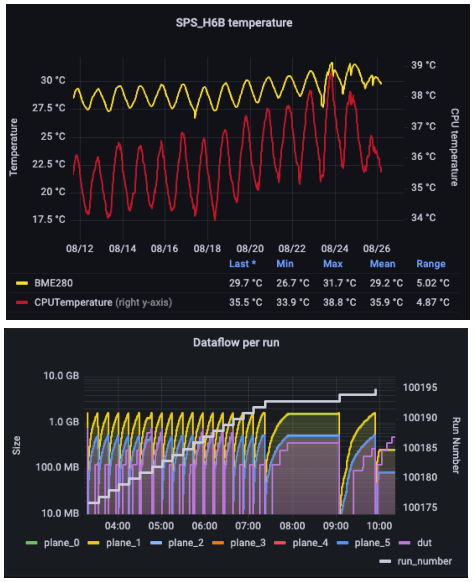
Telescope setup in H6B



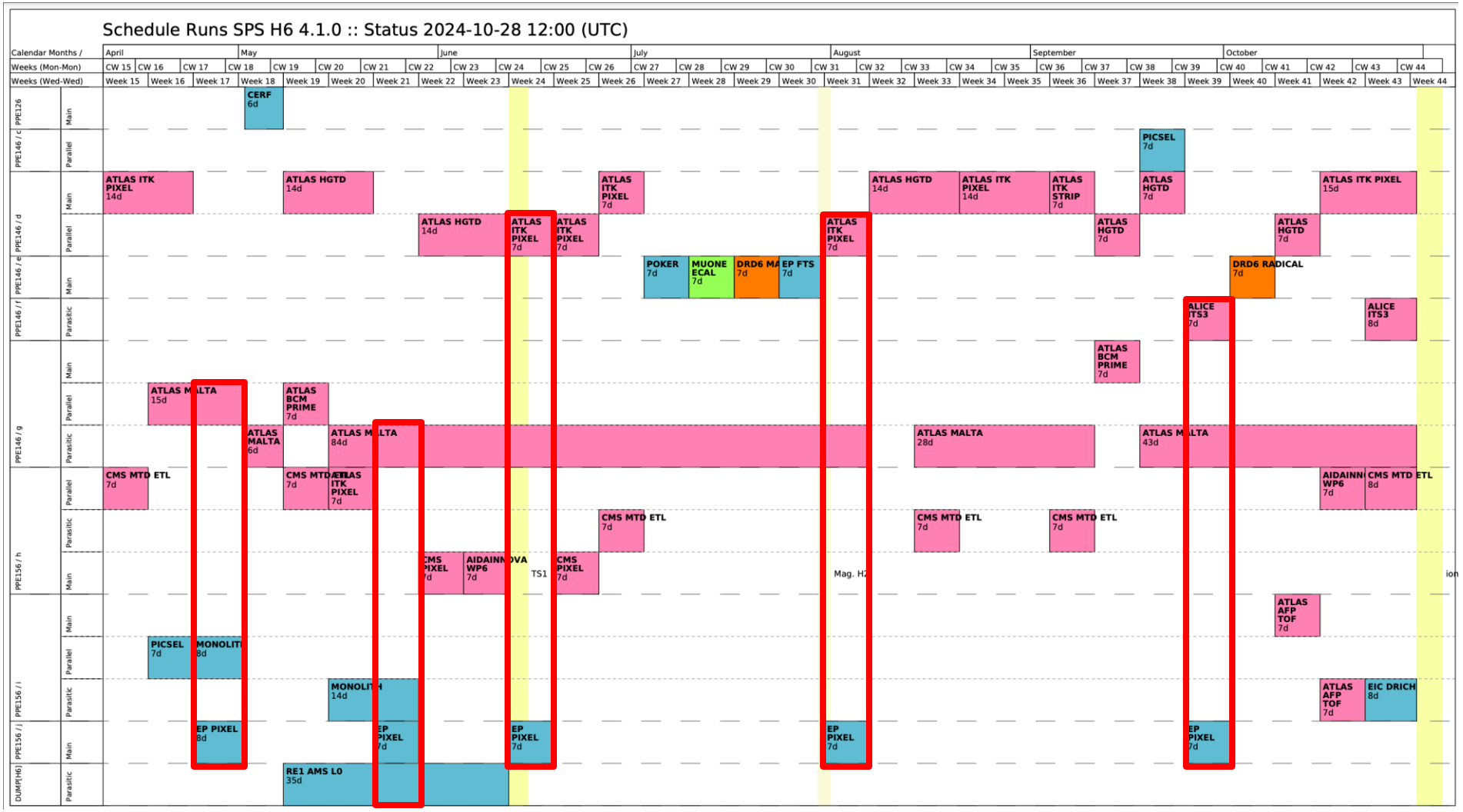
Telescope planes with H2M DUT



Grafana monitoring



2024 H6 high-rate data-taking



- 5 weeks of dedicated high-rate data taking in H6
- Beam time shared between EP PIXEL, MONOLITH, ATLAS MALTA, ALICE ITS3, ATLAS ITK Pixel

High-rate data-taking conditions

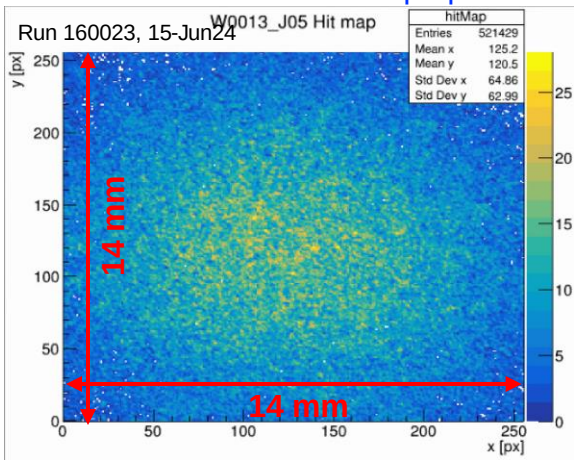
- Fast initial **beam tuning** at start of each high-rate week (using wire chambers and our telescope hit maps)
- Continuous **fine-tuning** of rates according to radiation monitors

→ **Thank you to Laurence and colleagues for the excellent support!**

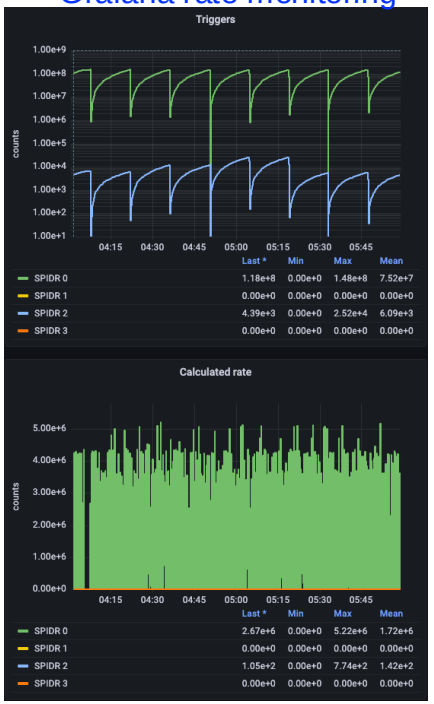
- High momentum pions (**~120 GeV**)
- Almost parallel beams of small size (**<1 cm x 1 cm**), focus on our H6B telescope
- **nominal beam** position defined in the beginning, kept stable for the entire year
  - → **efficient data taking** for everyone
- Some **re-tuning** of beam position following changes of target steering (e.g. polarity changes)
- High rates:
  - **Up to 4.5M / spill** in scint. 532 @ 3 spills / 43.2 sec SC
  - Limited by **integrated ionizing dose** in radiation monitors PAXNA14612 (bridge btw. H6A and H6B), PAXNA12612 (above shielding), and in neutrino-platform area
  - → achievable rate depends on **super-cycle composition** + data-taking conditions in **H8**
  - → **~ 20-30%** lower average rates in 2024 than in 2023

- **Very good collaboration** with upstream users in high-rate beam periods
  - Telescopes well aligned and rather stable DAQ in most setups
  - Efficient communication using H6 Mattermost channel (access etc.)

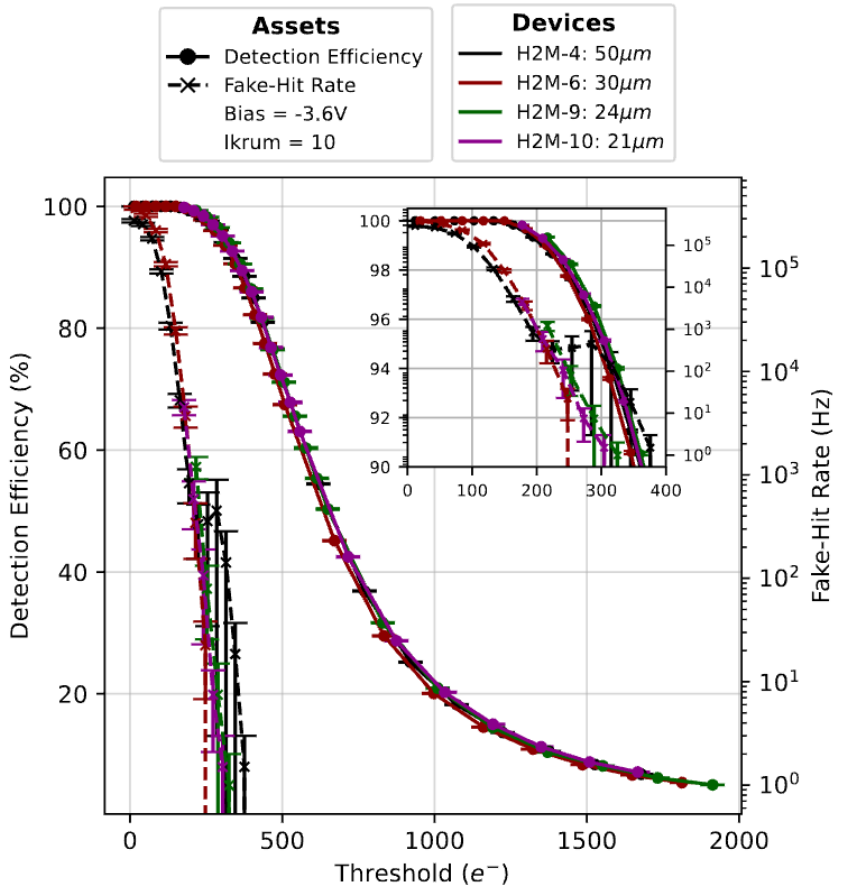
Beam observed in telescope plane

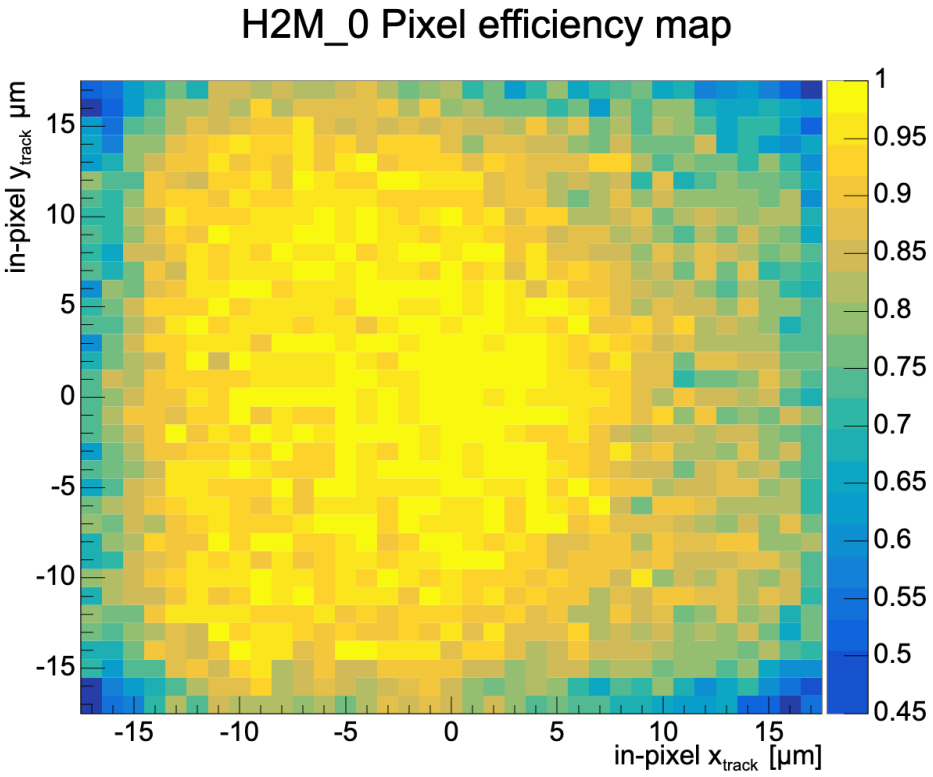


Grafana rate monitoring



H2M example results





Operation-parameter scans with high-statistic data sets
→ profit from high beam rates and efficient automated data-taking

Precision measurements of effects within the pixel cell
→ profit from high beam rates and high-resolution telescope tracking

Outlook

EP Pixel plans and requirements for 2025 and beyond:

- **EP R&D Phase II** approved for 2024-2028
- Testing plans:
  - **H2M** → further thinning studies below 20 µm
  - Hybrid timing detectors with Timepix3/4 and **TI-LGAD** sensors
  - Integration of Telepix region-of-interest **trigger plane**
  - OCTOPUS project for Lepton-Collider Vertex Detector → 1st submission in **2026**
- Similar as before: **high momentum pions at high rates** required
- Requested **4 weeks** of high-rate testing for 2025
- Preparing also for **LS3**
  → beam tests at DESY, requires integration in different telescope hardware

Wishlist:

- **Automatic rate adjustment (collimator settings)** based on observed radiation levels → higher instantaneous rates during periods with fewer spills / longer supercycles
- Additional **beam-profile monitors** near H6B telescopes for easier beam tuning
- Possibilitiy to run **Cesar** in monitoring mode on any non-Windows PC from remote (for us it currently only runs on Windows Terminal Server machines)