Test-beam and irradiation facility at the 25 MeV proton cyclotron CYRCé at Strasbourg

9th edition of the Beam Telescopes and Test Beams Workshop

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On Behalf of the CMS Tracker Group

Context

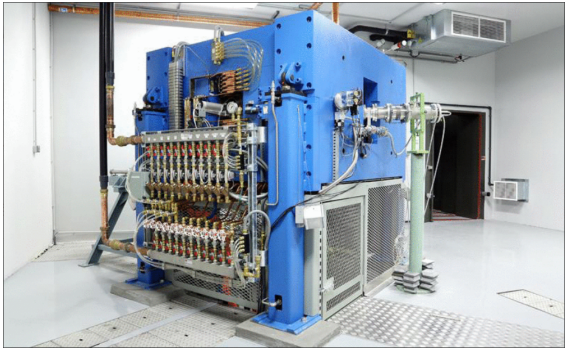
- 2027: LHC enters the high luminosity stage (HL-LHC)
  and this marks the start of the **Phase-2** run
- To cope with **HL-LHC** operating conditions (high rate, high radiation,...)
  CMS needs a completely new Tracker detector:
  - **Inner tracker**: **pixel modules**
  - **Outer tracker**: **strip-strip (2S) modules**, **pixel-strip (PS) modules**

  } Strasbourg team contribution
- Ongoing **R&D** $\Longrightarrow$ **requires Test Beam Facilities**
- **prototypes need to be tested**
  - ⋆ *performance, maintenance, cooling, high rate, radiation, ...*

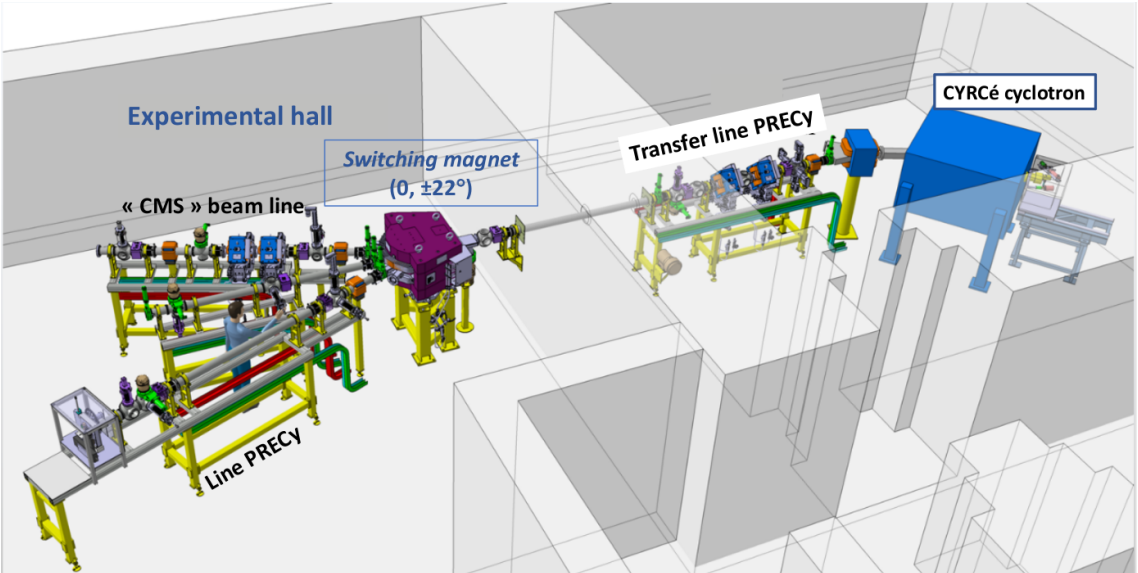
Test-Beam facility at Strasbourg

CYRcé Cyclotron pour la Recherche et l'Enseignement

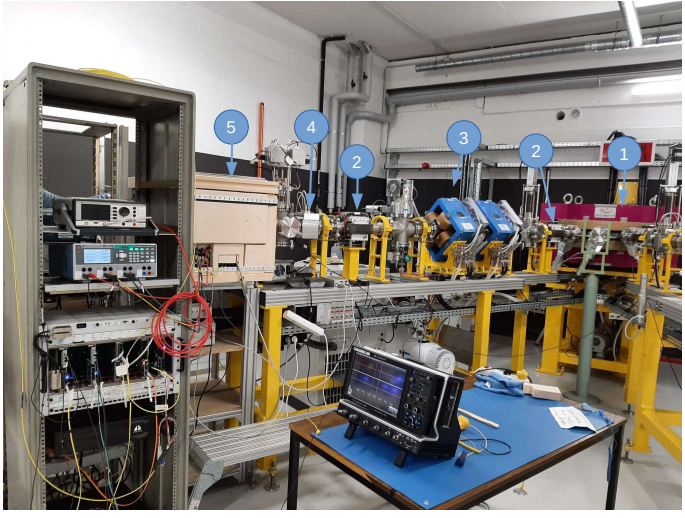
- **Beam energy : 16-25 MeV protons**
  - ↪ *large energy deposition* (~ 11×MIP)
  - ↪ *range in Silicon: about 3 mm*
- **Bunch clock frequency: 85 MHz**
  - ↪ *reduced to* **42.5 MHz** *by a "kicker"*
  - ↪ *close to LHC clock*
- **High intensities : up to 100 nA**
  - ↪ *high rate* (up to $\sim 6 \times 10^{11}$ protons/s)
- **Beam spot**: 2 mm to 30 mm ⌀



Beam lines


Experimental hall
Switching magnet
(0, ±22°)
« CMS » beam line
Transfer line PRECy
CYRCé cyclotron
Line PRECy

CMS Beam line

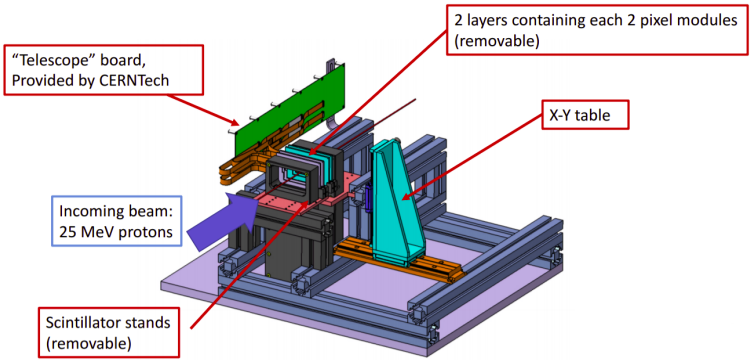


1. **Switching magnet**
2. **X-Y steerer**
3. **Q-poles**
4. **X-Y profiler**
5. **Experimental setup**
   with preliminary thermal insulation

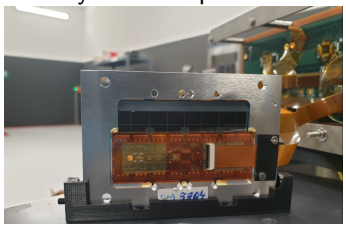
CHROMini Telescope (Phase-1 pixel modules)

Mini version of CHROMIE Telescope *under commissioning...*

Design of the Telescope



One layer with 2 pixel modules



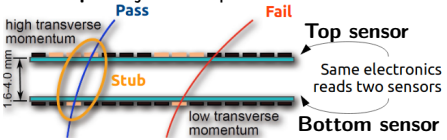
CMS Phase-1 pixel module

Active area 16.2×64.8 mm^2

16 readout chips per module

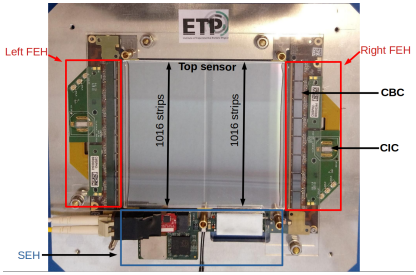
Device Under Test (DUT): 2S module

Concept: reject low-pT tracks



correlates hits: stubs

built by ETP-KIT



2×1016 strips per sensor (Top/Bottom)
strip length: 5 cm, pitch: 90 μm
Active area: $\sim 90 \times 90$ cm^2, $\sim 2 \times 290$ μm thick

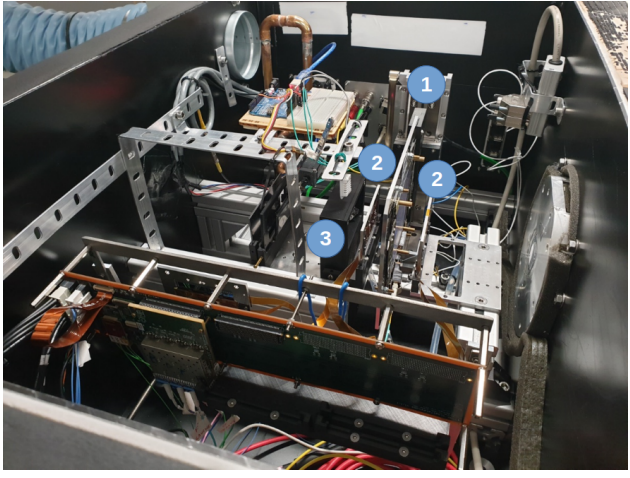
Front-end hybrid (FEH)

- 2×8 CMS Binary Chip (CBC)
  Each chip reads out 2×127 strips
  Inter-chip communication
- 2×1 Common Concentrator IC (CIC)
  Buffers, aggregates, and sparsifies each CBC's data

Service hybrid (SEH)

- HV/LV connectors, DC-DC converter,
  (Lp)GBT distributes clock & trigger,
  data from left & right FEHs are merged and sent via optical link to the back-end @ 5.12 Gb/s (10.24 Gb/s)

Setup



1. **2S module** on a sliding support (2D)
2. **Pixel Telescope**: 2 layers of pixels
3. **Scintillator**: trigger (NIM logic)

- **cooling system**

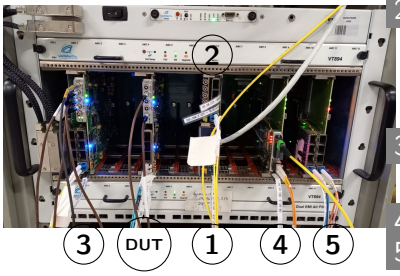
dry air or water cooling

- T° & Humidity sensors

DAQ and Control System: for the Telescope and the DUT (2S module)

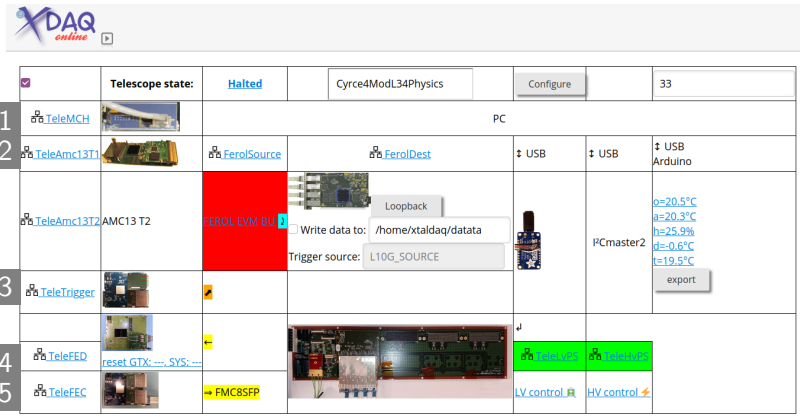
Back-end

μTCA



μTCA can hold up to 12 full size AMC cards

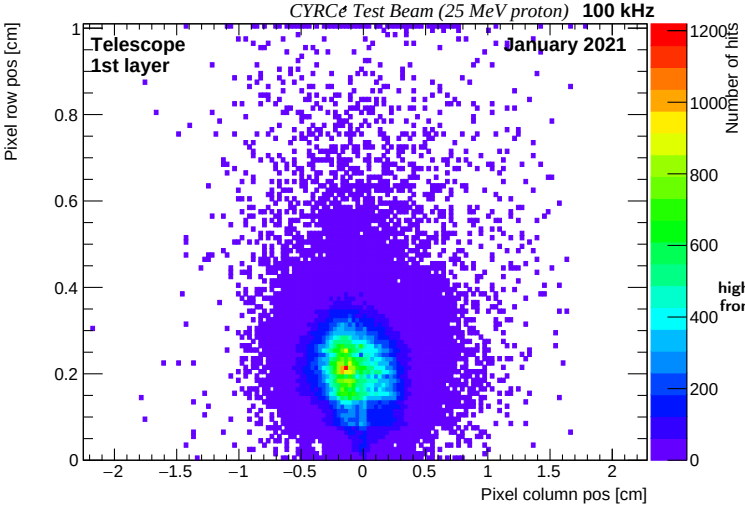
1Gb/s Ethernet network access to all cards through MCH (MicroTCA Carrier Hub)

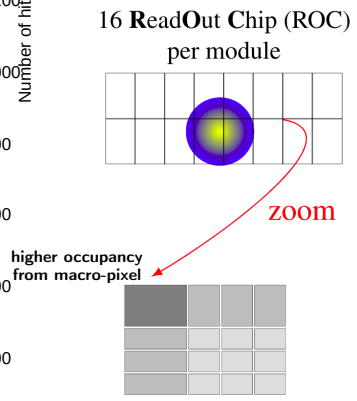


For DUT, only remote control of power supplies is used

Beam profile with Telescope (Phase-1 pixel modules)

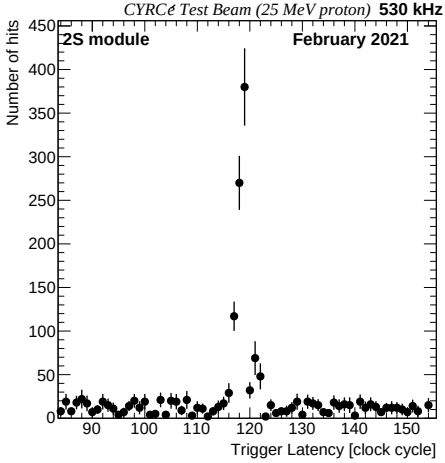
2D (column,row) hit occupancy map for a pixel module of the 1st layer

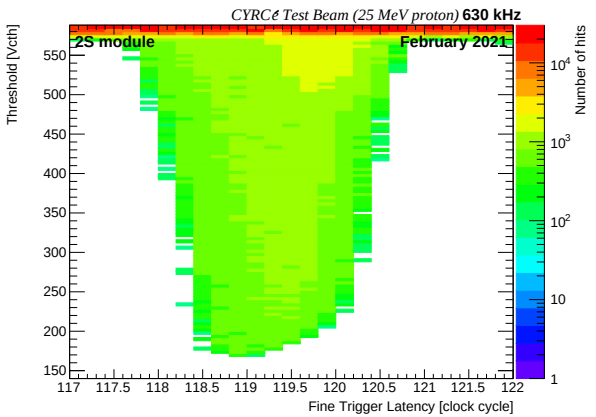




Latency scan with DUT (2S module)

Latency scan: to read the right data for each trigger
time between event & arrival of trigger

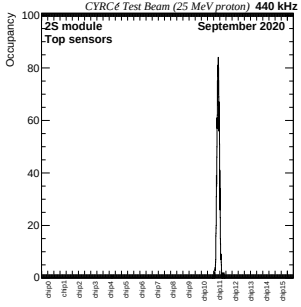


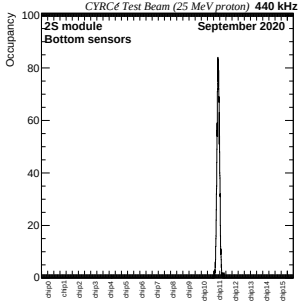


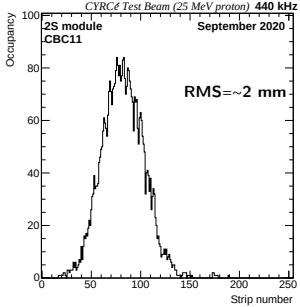
Fine latency scan by retuning the PLL delays.

Beam profile with DUT (2S module)

Hit occupancy map for the 2S Module (top and bottom sensors)



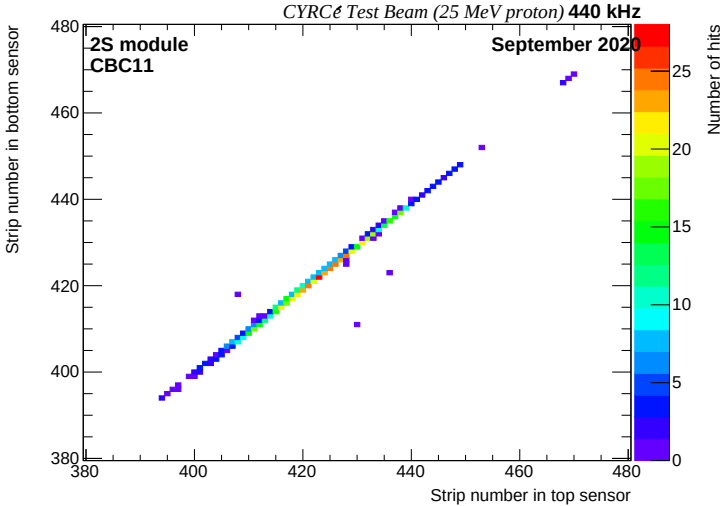




Collimated beam: signal readout by one chip (CBC)

Hit correlation between the two sensors of the 2S module (DUT)

Correlation between the hits in the top and the bottom sensors



Summary & Outlook

- **CYRCé** can be used for
  - ⋆ **High rate tests**
  - ⋆ **Radiation tests**
- Being used for the CMS 2S module (DUT)
  - ⋆ **2S module characterization**
  - ⋆ **Pixel telescope commissioning**
- Other DUT than the 2S module
  - ⋆ already irradiated DC-DC converters of the CMS Phase-1 pixel
  - ⋆ module of the ATLAS timing detector (last month)

Outlook

- ◦ Finalise the **Telescope commissioning**
- ◦ **Central trigger** to synchronize events from 2S module and Telescope (TLU, ...)
- ◦ Perform **high rate tests**

Teams

- **IPHC-Strasbourg team**

  J. Andrea, C. Bonnin, J-M Brom, L. Charles, C. Collard, C. Grimault, U. Goerlach, T. Goeltzenlichter, L. Gross, M. Krauth, E. Nibigira, N. Ollivier-Henry, S. Veeramooto, M. Pellicioli, J. Schuler, T. Foehrenbacher, M. Rousseau, C. Haas, C. Mathieu, C. Ruescas

- **KIT (Karlsruhe)**

  S. Maier, A. Dierlamm (KIT)

- **Inst. of Nucl. Phys. (Demokritos)**

  P. Asenov, D. Loukas

- **Significant help from**

  N. Deelen(+CHROMIE team), D. Kotlinski, V. Veszpremi, M. Tsirou, J. Sonneveld, S. SeifEl Nasr, S.Mersiand

many others


Backup

Kicker (resonant circuit)