ALICE FoCal

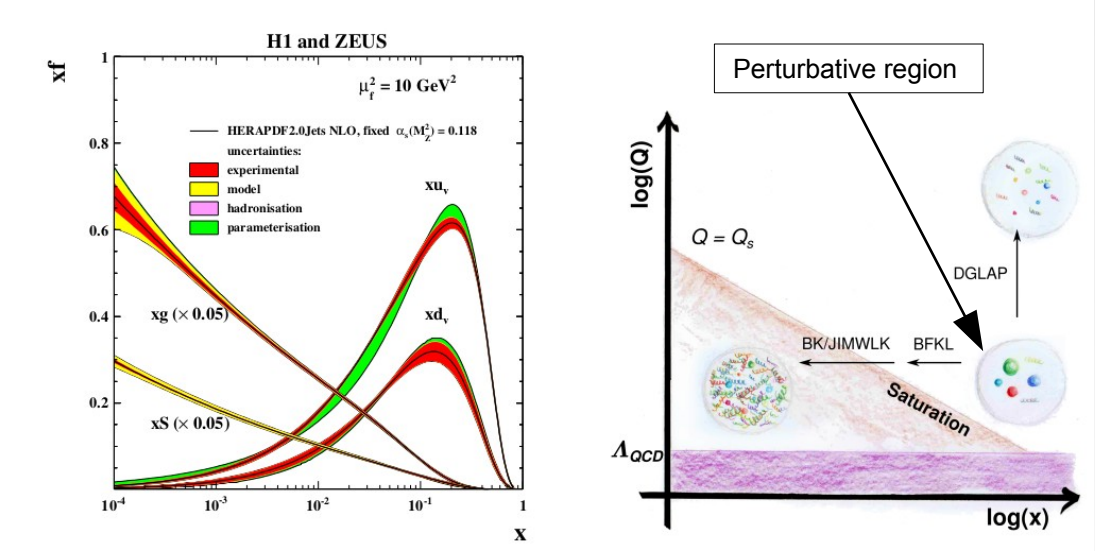
A Forward Calorimeter for the ALICE Experiment

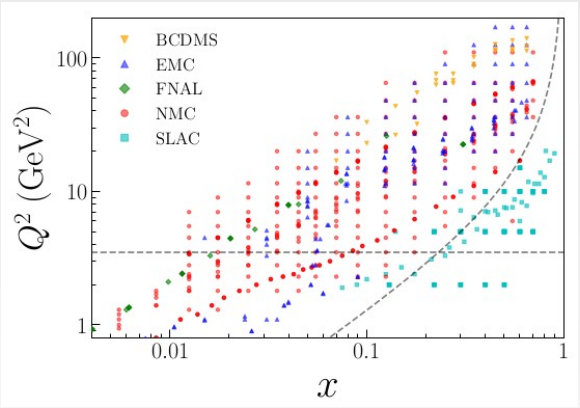
Max Rauch for the ALICE Collaboration

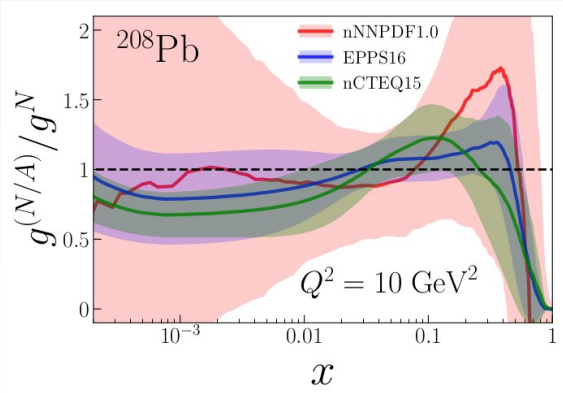
ICHEP 2022, Bologna

UNIVERSITY OF BERGEN

Nature of gluon saturation at low x

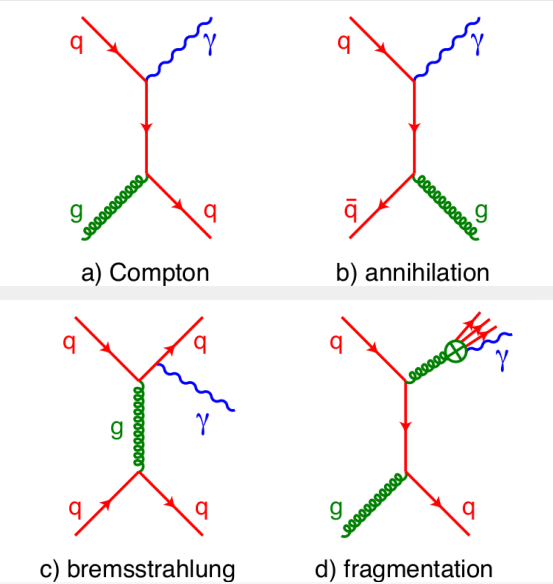


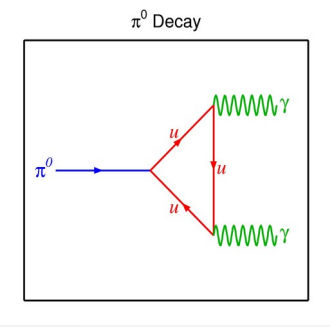


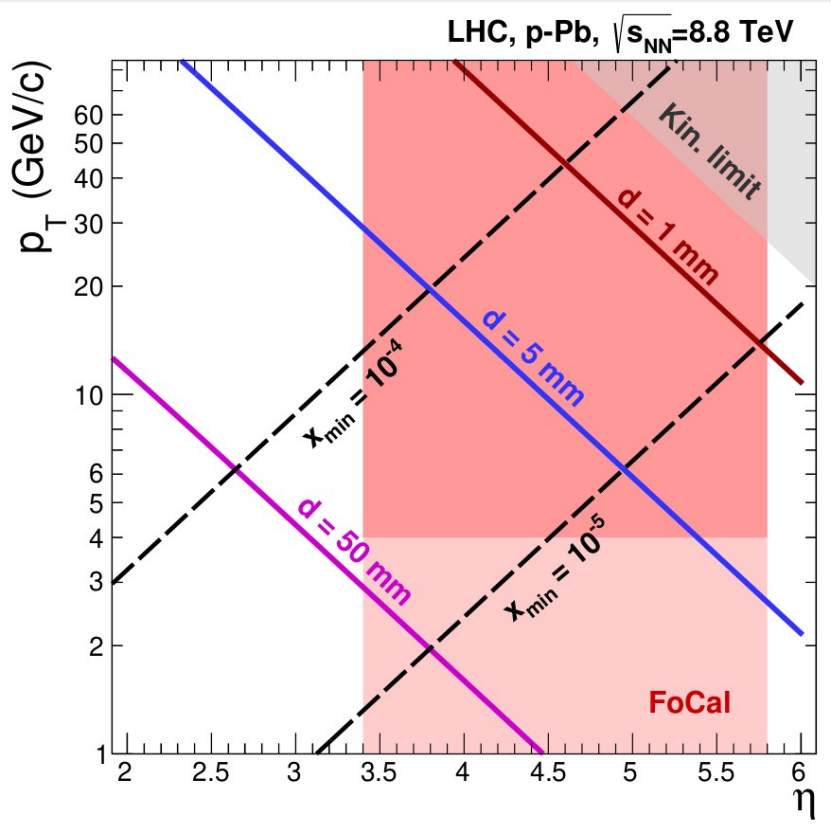


- PDFs determined from deep inelastic scattering, neutral current or DY processes → region of perturbative QCD
- Linear evolution towards higher Q^2 (“DGLAP”) and towards lower ***x*** (“BFKL”)
- At even lower ***x*** with higher **gluon densities (saturation)** non-linear evolution becomes relevant (“BKJ/JIMWLK”)

Single isolated photon signal events





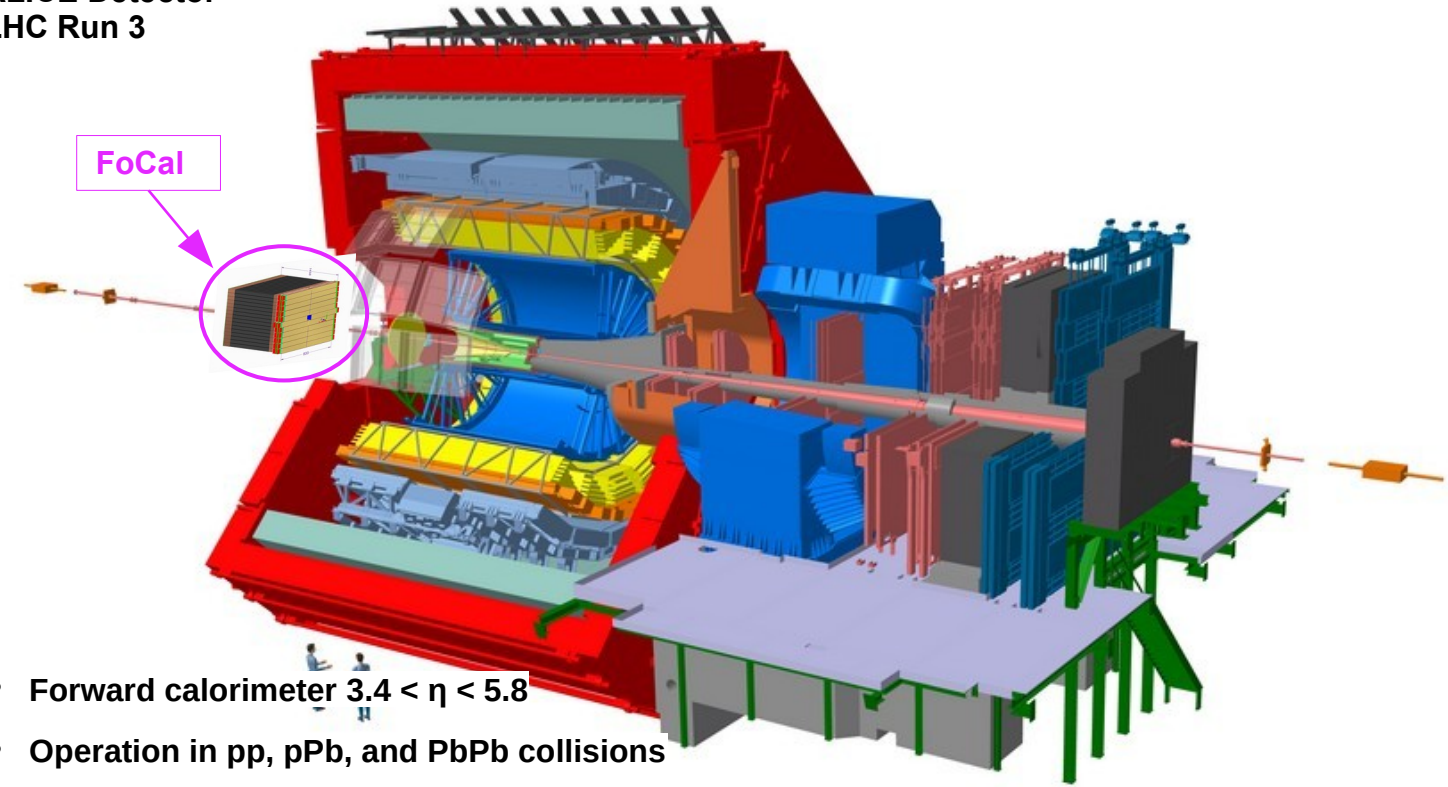


- **Single isolated photons** in forward direction
  - Discrimination of π_0 decay into two ɣ
  - Isolation from hadronic activity / jets
- **ALICE Fo**rward **Cal**orimeter → **ALICE FoCal**
- Other motivations not mentioned here hold as well

The FoCal detector in ALICE

ALICE Detector
LHC Run 3

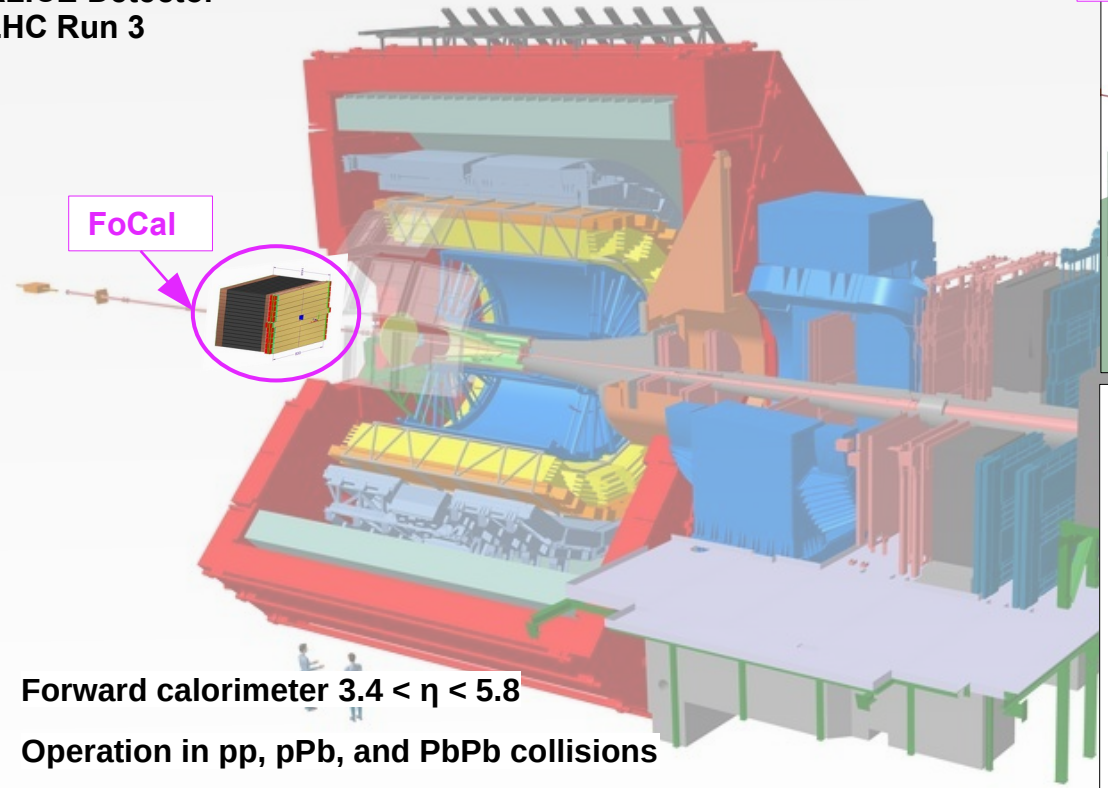
Not to scale

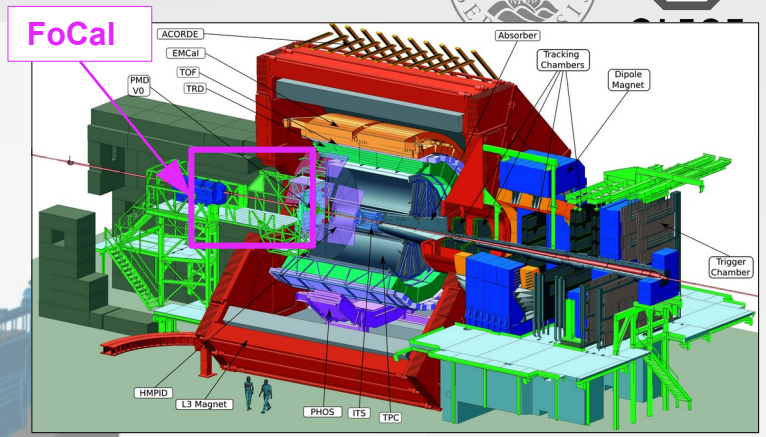


- **Forward calorimeter 3.4 < η < 5.8**
- **Operation in pp, pPb, and PbPb collisions**
- **Installation in ALICE foreseen for LHC Run 4 (2029)**

The FoCal detector in ALICE

ALICE Detector
LHC Run 3





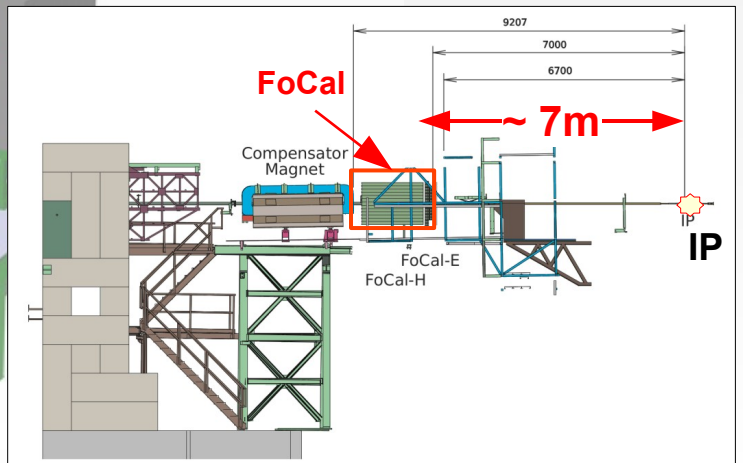
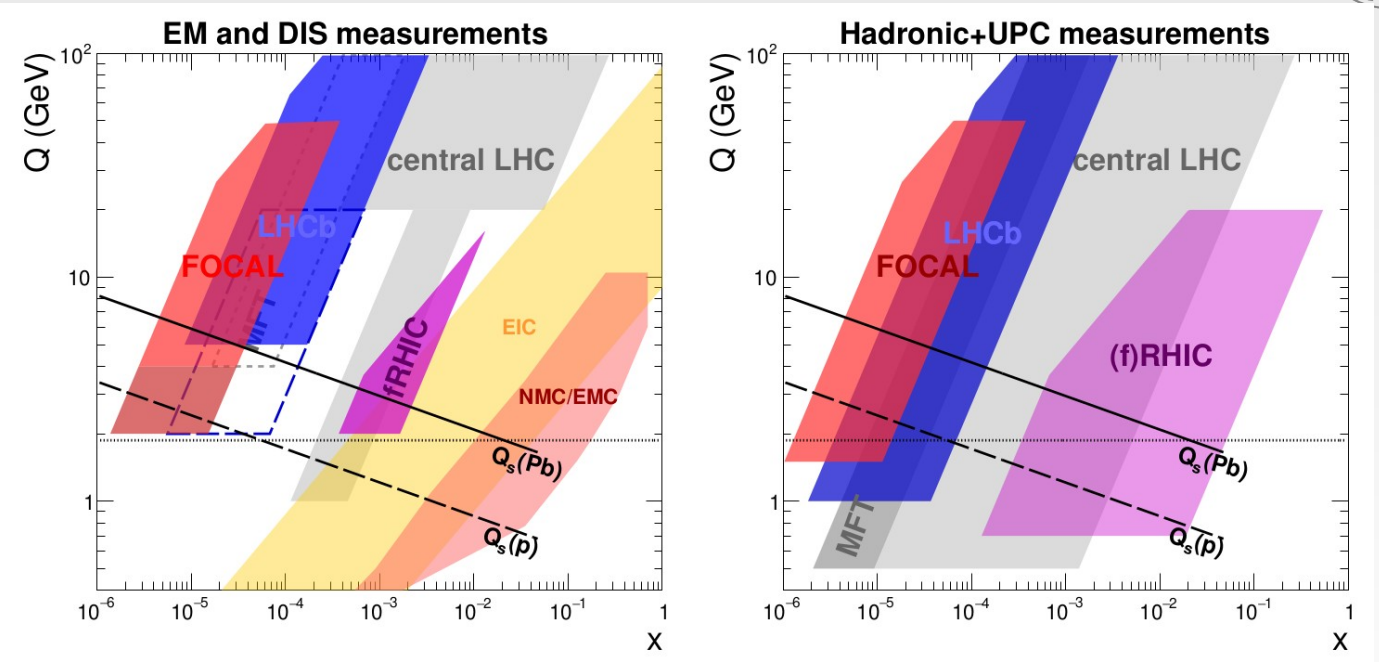


Fig. 19: Installation of the FoCal at the 7m location with FoCal-E and FoCal-H detectors.

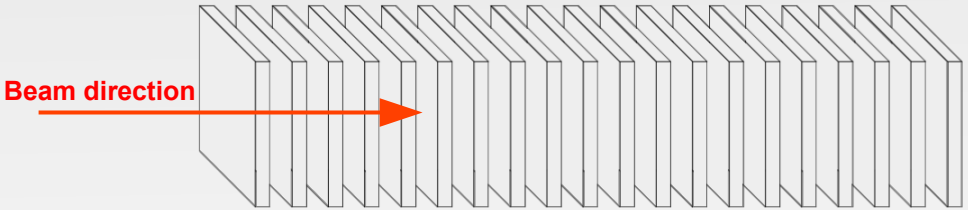
- **Forward calorimeter $3.4 < \eta < 5.8$**
- **Operation in pp, pPb, and PbPb collisions**
- **Installation in ALICE foreseen for LHC Run 4 (2029)**

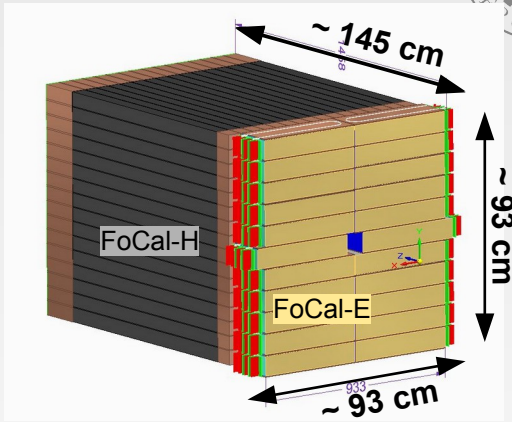
The FoCal detector in the Q-x-plane



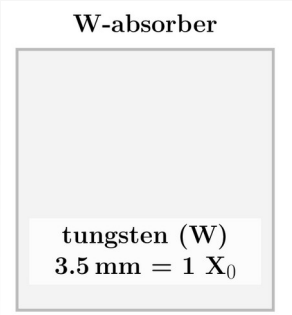
FoCal extends the experimentally accessible Q-x-domain!

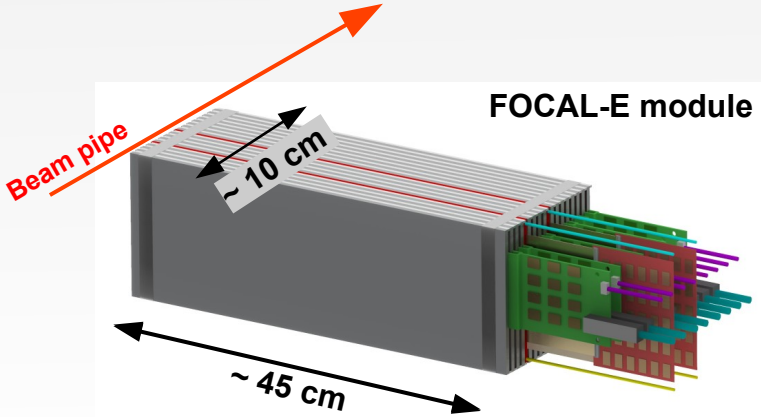
ALICE FoCal detector design



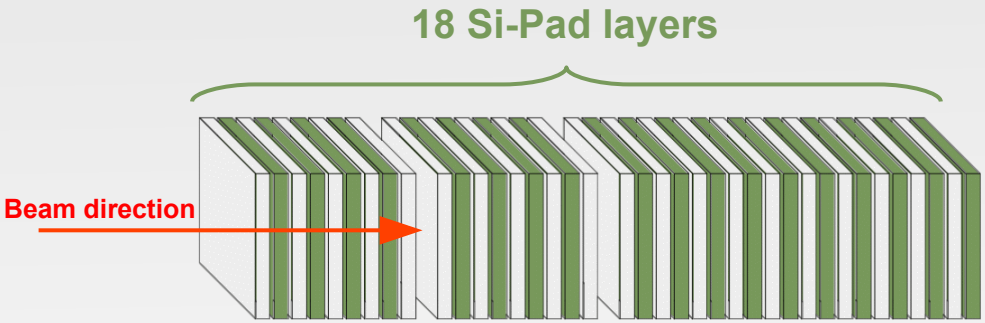


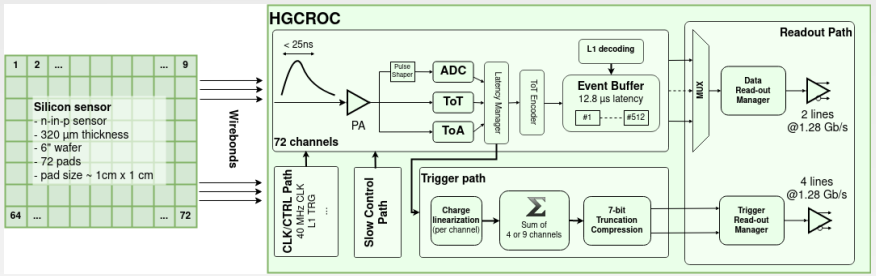
- FOCAL transverse active size ~ 90 cm x 90 cm
- 20 tungsten plates as absorber material
- Atomic number Z = 74
- Density of 19.28 g/cm³
- Thickness of 3.5 mm = 1 X_0
- Radiation length: 20 X_0
- Molière radius ~ 1 cm
- Total layer thickness ~ 5 mm

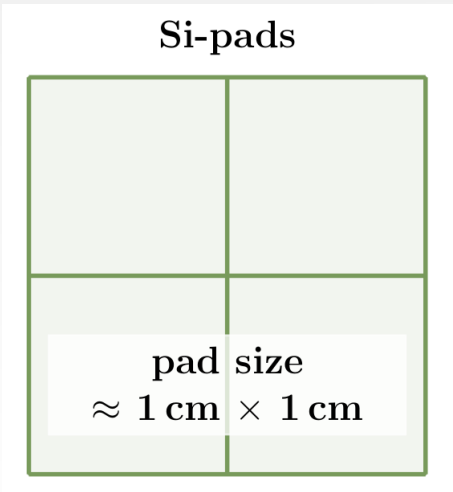




ALICE FoCal detector design

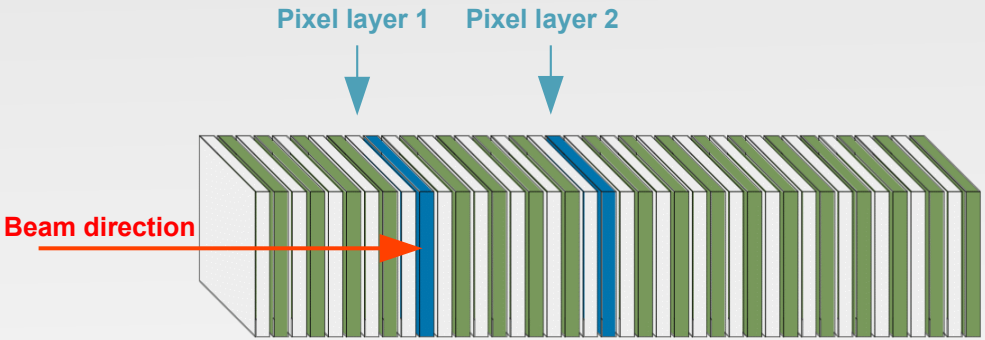


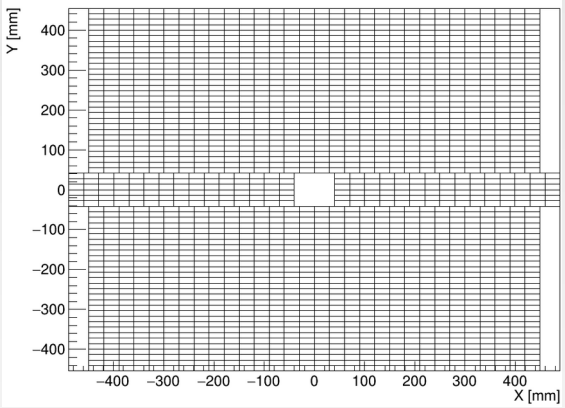




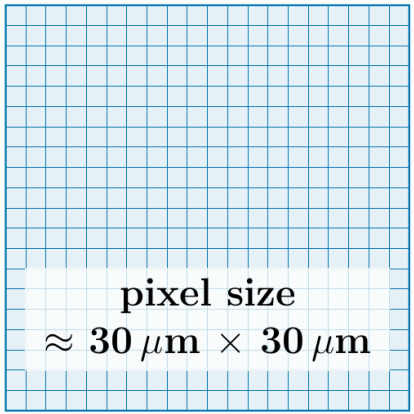
- Silicon sensor with pad size of ~1 cm x 1 cm
- 8 x 9 pads per sensor
- Each sensor read out with one HGCROC
- Charge measurement per pad with ADC, ToT, and ToA
  - High dynamic range: MIP ↔ 10 pC
- Fast trigger signal derived from HGCROC
- Longitudinal shower profile information for each layer

ALICE FoCal detector design



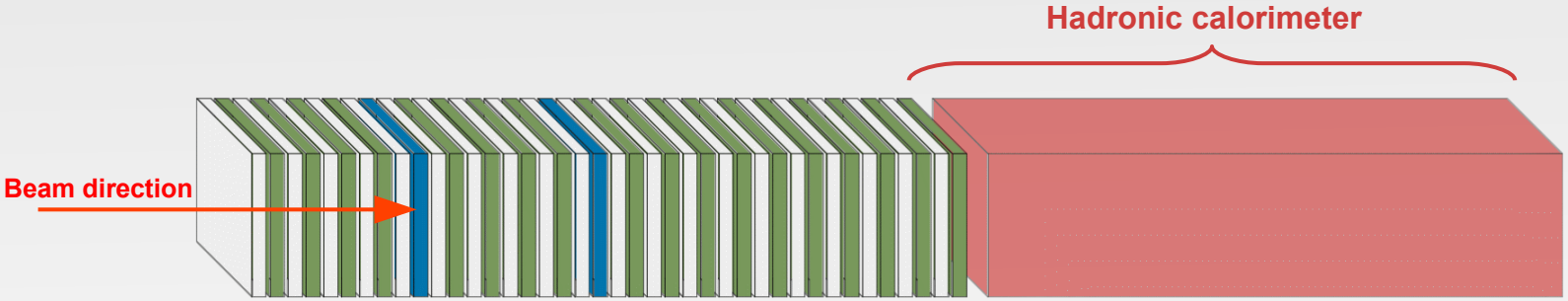


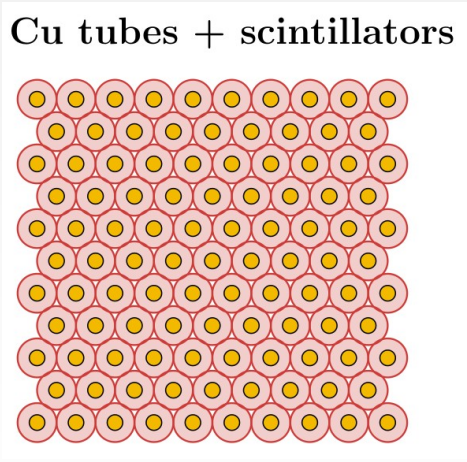
Alpide pixel sensor



- ALPIDE pixel sensor (ALICE ITS vertex detector pixel sensor)
- Silicon monolithic active pixel sensor with pixel size of ~30 μm x 30 μm
- 1024 x 512 pixels per chip
- Chip size ~30 mm x 15 mm
- Time constant of analog front-end ca. 5 μs
- ~ 2000 ALPIDEs used per layer
- Two-shower separation at the mm-scale

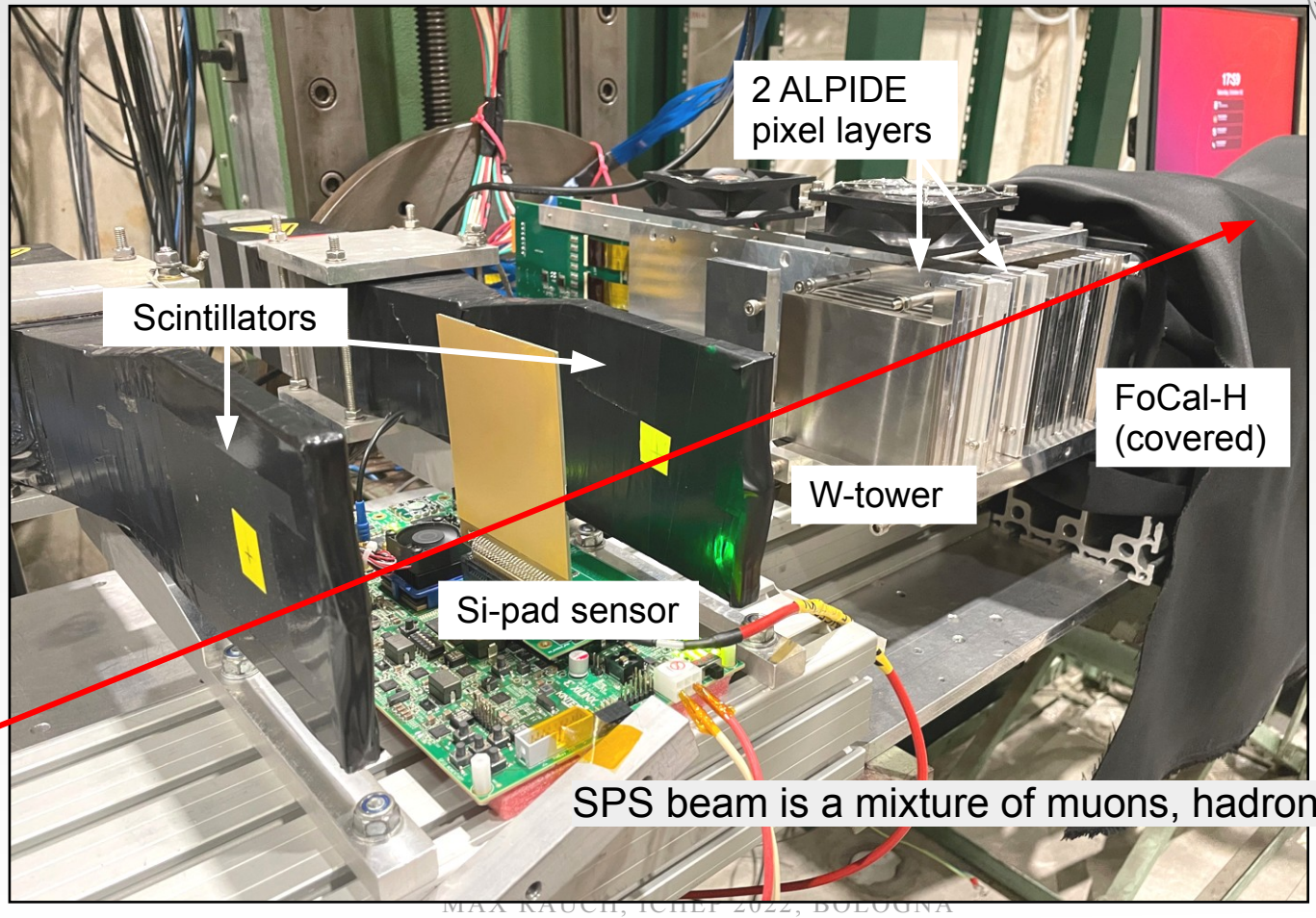
ALICE FoCal detector design





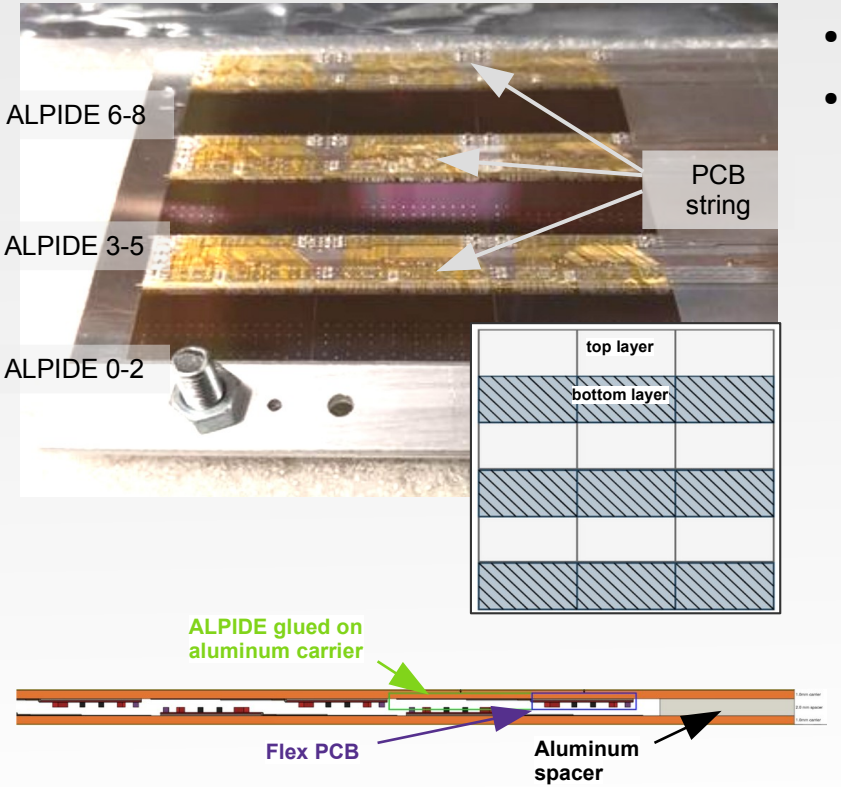
- Copper tubes parallel to beam pipe (diameter 2.5 mm)
- Filled with scintillating fibers (diameter 1.1 mm)
- Fibers coupled to silicon photomultipliers
- Prototype 1 from 2021
  - 95 x 95 x 550 mm^3
  - 1440 copper tubes
- Prototype 2 from 2022
  - 65 x 65 x 1100 mm^3
  - 668 copper tubes per module
  - 9 modules planned

CERN SPS beam test 2021



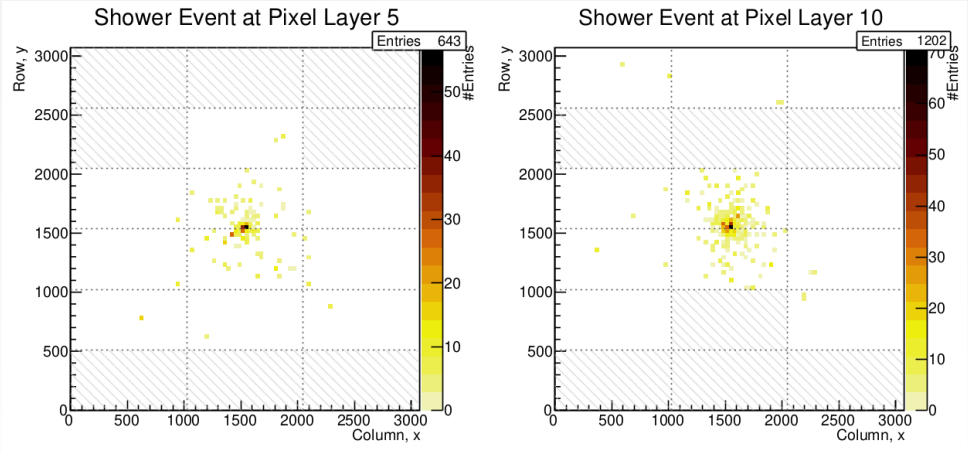
SPS beam is a mixture of muons, hadrons, electrons.

FoCal-E pixel layers (CERN SPS 2021)

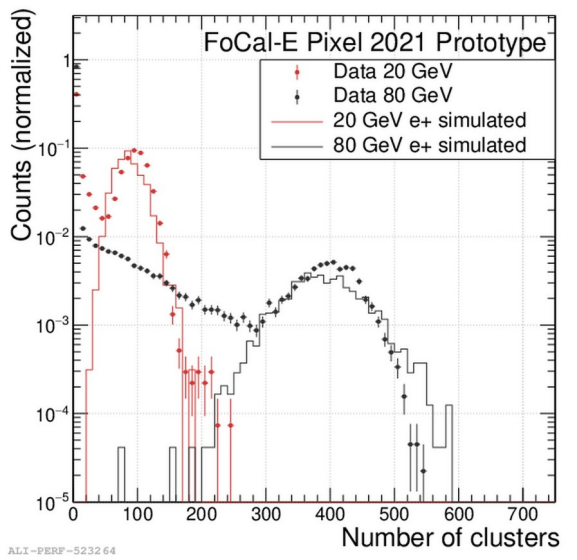


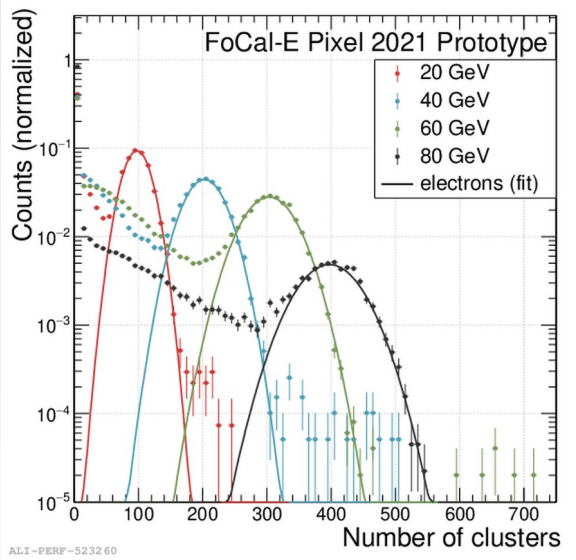
- 4 half-layers with 36 Alpide chips
- Energy measurement by number of fired pixels

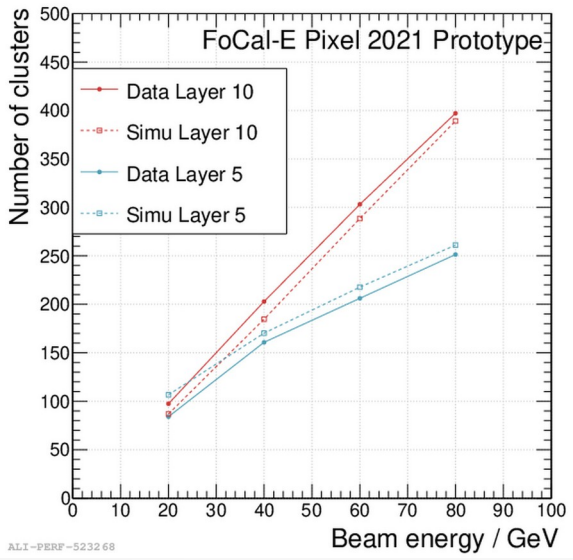
Example of an electromagnetic shower in both pixel layers



FoCal-E pixel layers (CERN SPS 2021)



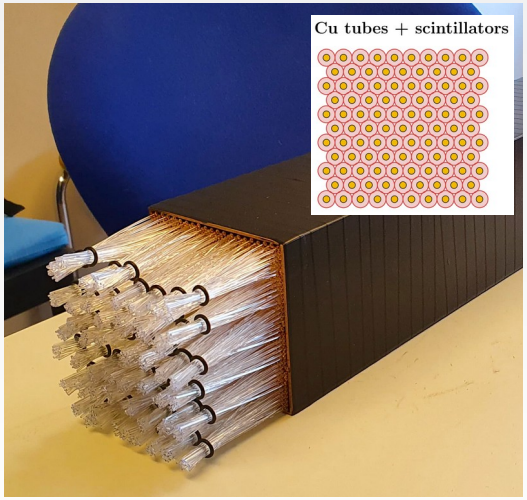


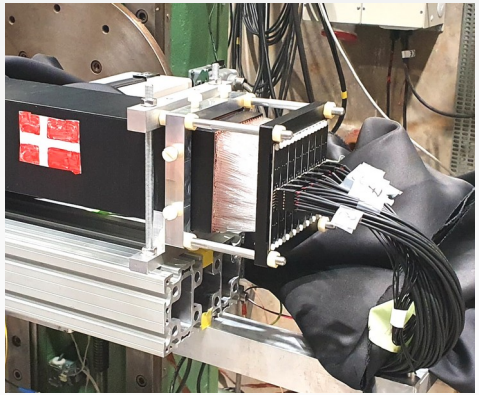


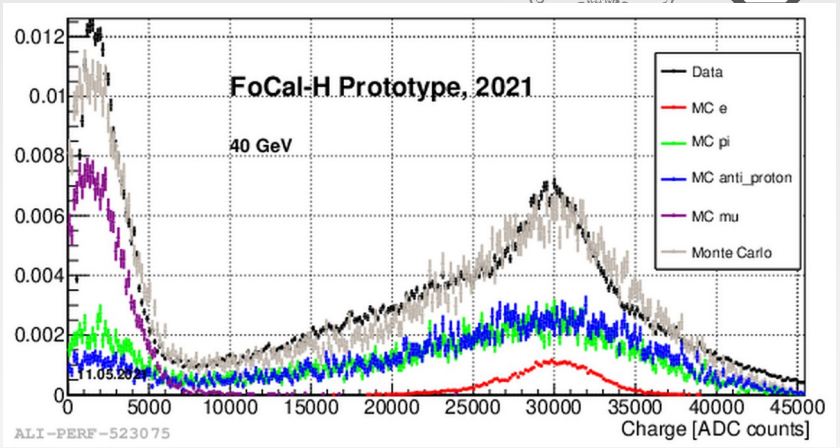
- Signature of all particle types measured in pixel layers
- Measured and simulated positions of signal peak compatible within ~10% or better
- Electron peak measured for energies between 20 and 80 GeV

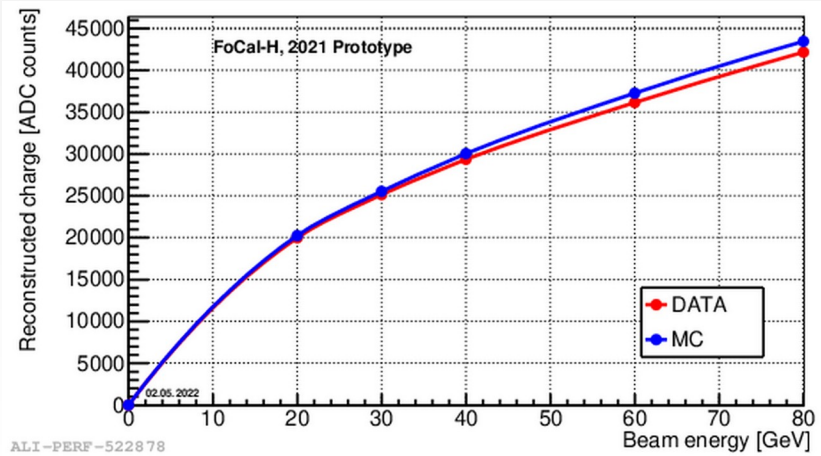
FoCal-H results (CERN SPS 2021)

- 1440 copper tubes and scintillating fibers
- 42 readout segments connected to SiPM sensors
- Energy measured by sum of charge signal from SiPMs (in units of ADC counts)
- Commercial readout system with limited dynamic range: non-linearity at high energy

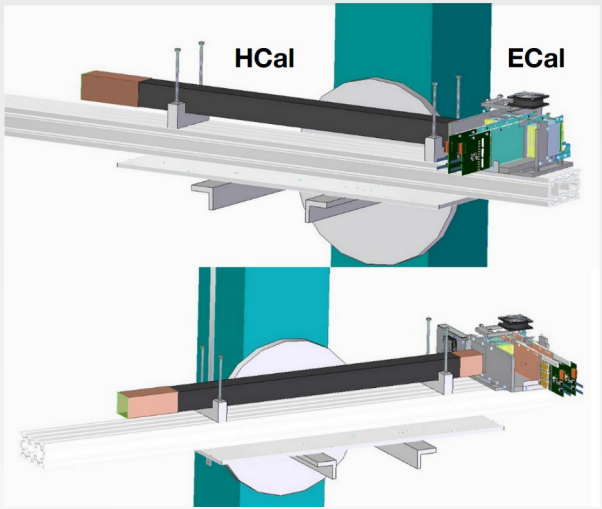


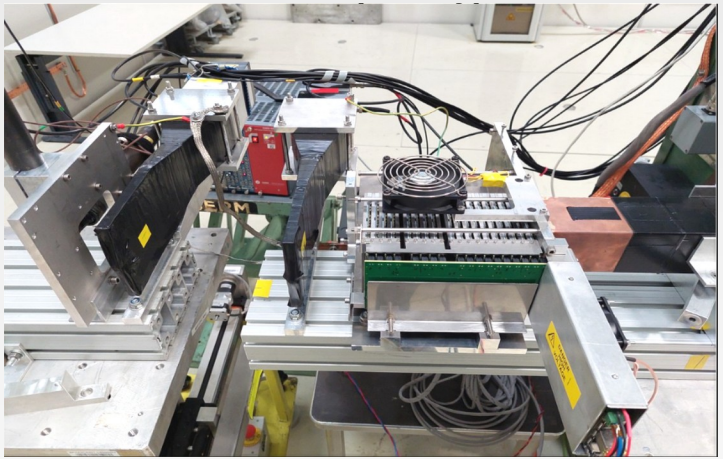






CERN PS beam test June 2022

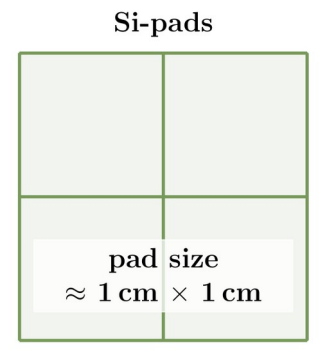


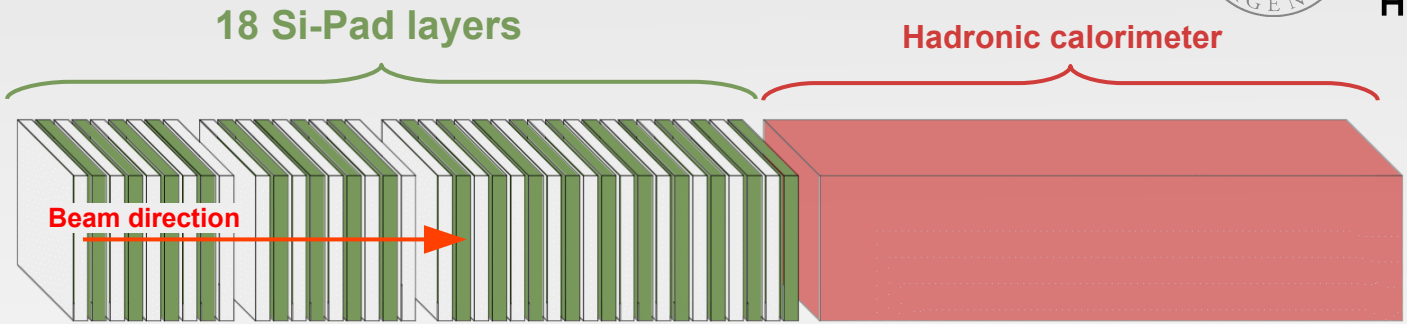


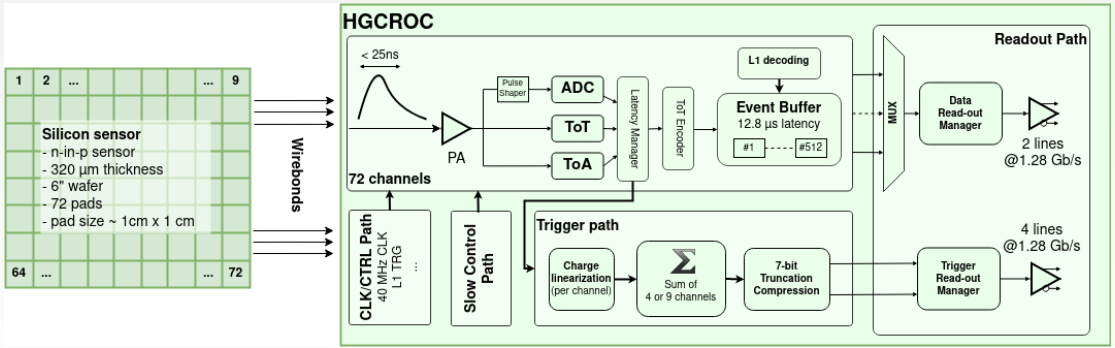
- Test of 18 FoCal-E pad layer system
- Test of FoCal-H Prototype 2 with length of 110 cm
- PS tests at low-energy range

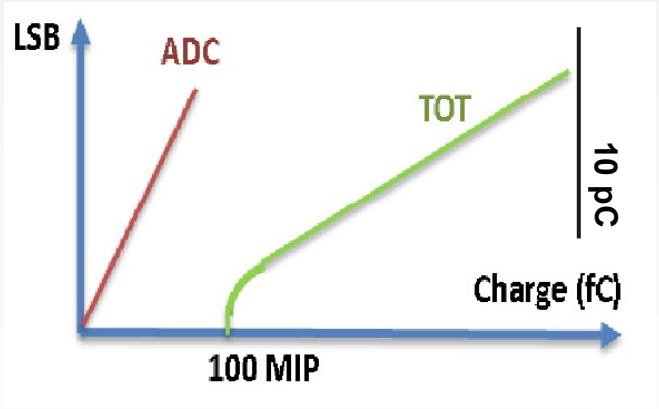
  → further tests planned at SPS for autumn 2022

Pad readout with HGCROC

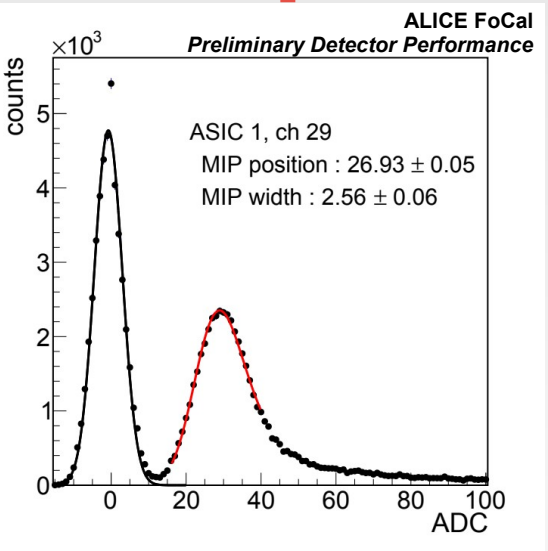


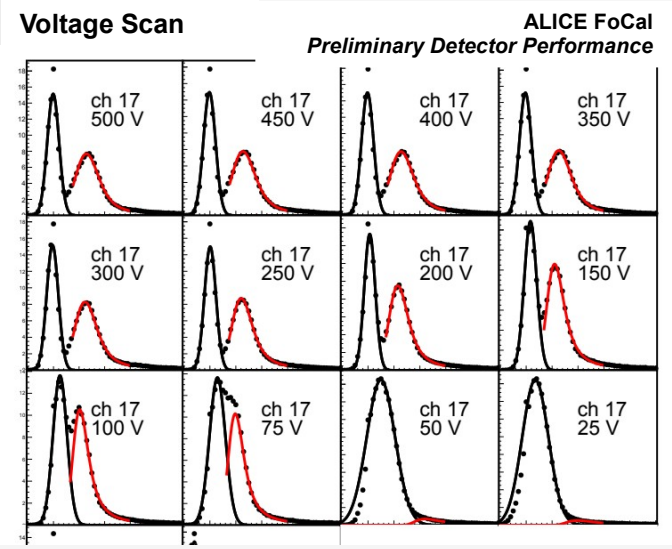


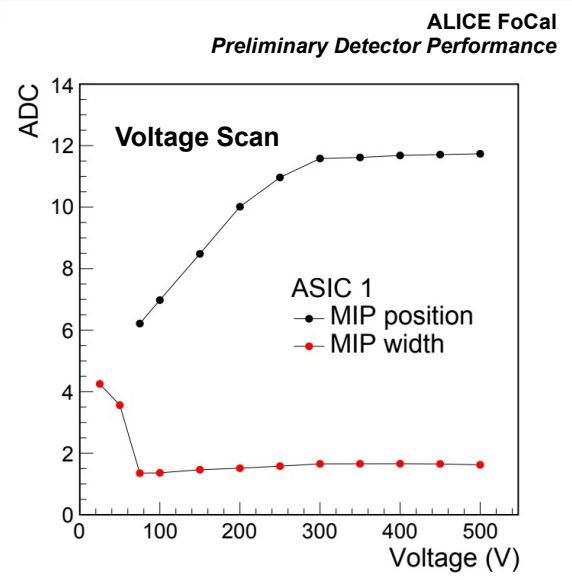




FoCal-E pads results (CERN PS 2022)







- Clear separation of MIP peak and pedestal noise measured in ADC distribution
- Separation measured in HV scan from 0 V to 500 V
- Starting to look in position and layer dependent effects, …
- Full energy and energy resolution scan at SPS Beam Test 2022

Summary + Outlook

- ALICE FoCal is a unique opportunity to measure isolated photons at LHC at high rapidities
- To be operated in LHC Run 4 starting from 2029
- Many tests of subdetector prototypes ongoing
  - Successful testbeam campaign with prototypes for FoCal-E and FoCal-H in 2021 and 2022
- Planned beam tests at CERN SPS for September and November 2022
  - Full system test with all subdetector systems at high energies
- Technical Design Report planned for 2023

ALICE Upgrade talks now:

- Magnus Mager: **A truly cylindrical inner tracker for ALICE**
- Nicolo Jacazio: **ALICE 3**

Backup Slides

FoCal-E pixel readout (CERN SPS 2021)

- All quasi-final components of the readout system tested
- ALICE Local Trigger Unit for providing the trigger signal
- ALICE ITS Readout Unit for ALPIDE readout
- First Level Processor unit with ALICE Common Readout Unit and ALICE O2 framework
- ALPIDEs successfully operated in
  - Scintillator triggered mode
  - 100 kHz periodic LTU triggered mode