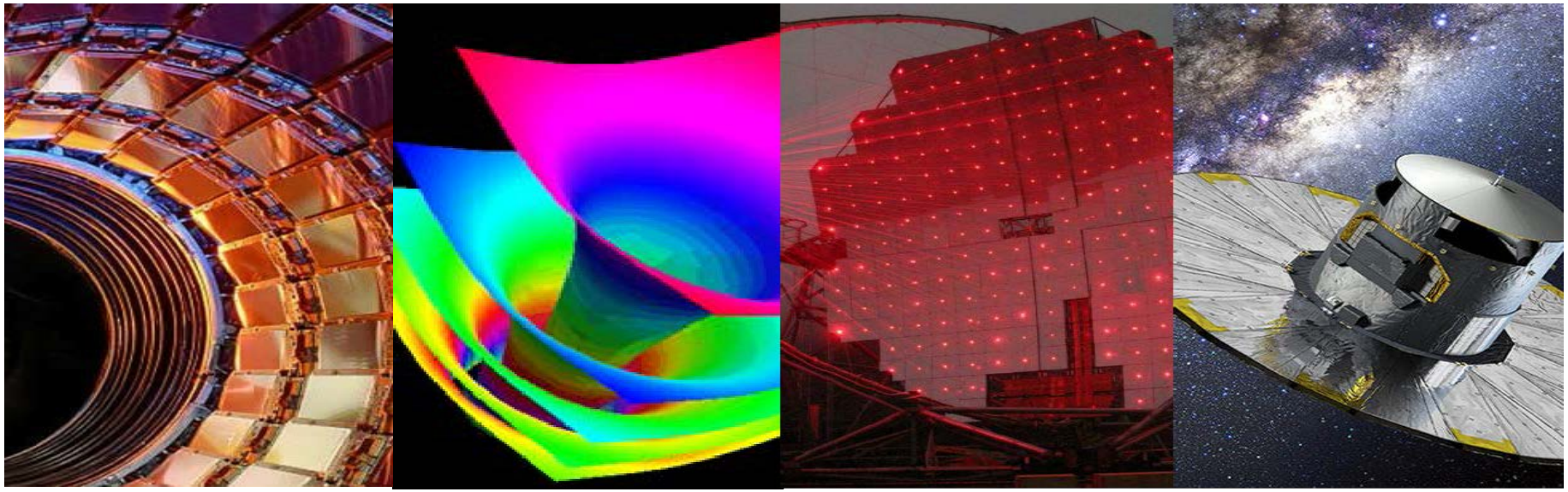
Institute of Cosmos Sciences

EXCELENCIA MARÍA DE MAEZTU



ICCUB Detector R&D

David Gascón

Technical coordination

On behalf many ICCUB colleagues

Institute of Cosmos Sciences

Universitat de Barcelona

Instrumentation for the future of particle, nuclear and astroparticle physics and medical applications in Spain

IMB-CNM

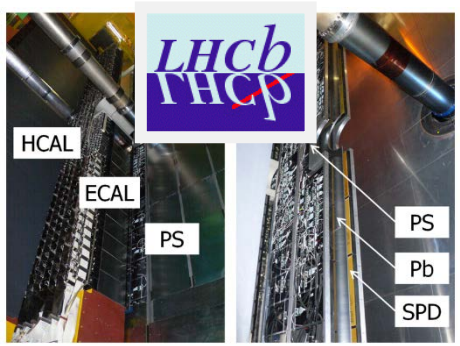
06/03/2023

http://icc.ub.edu/technology

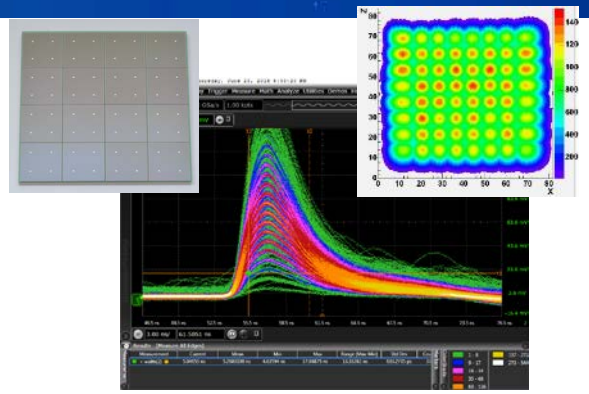
UNIVERSITAT DE BARCELONA

Introduction: R&D on detector technology

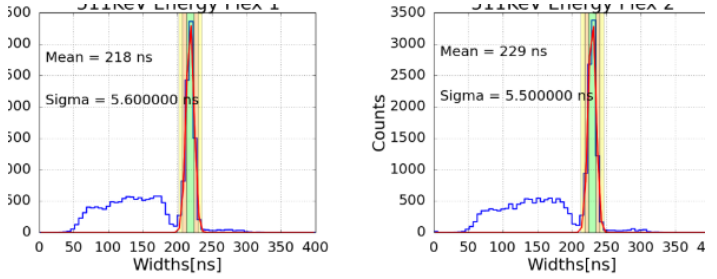
Telescope cameras

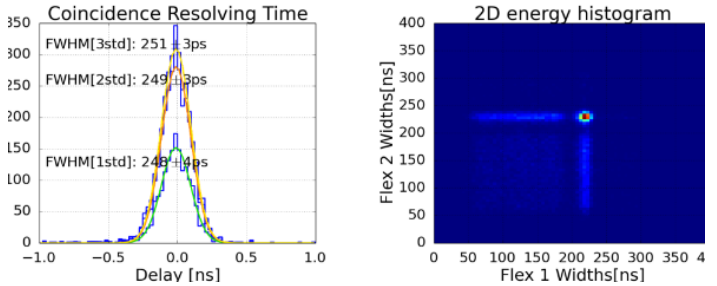


Particle detectors at CERN



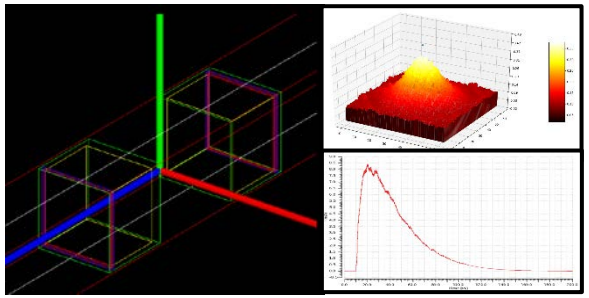
Single-Photon Sensors



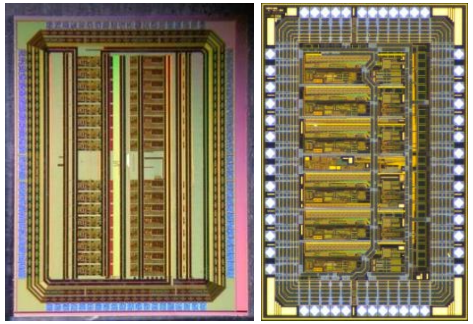


Positron Emission Tomography with Time-of-Flight (ToF-PET)

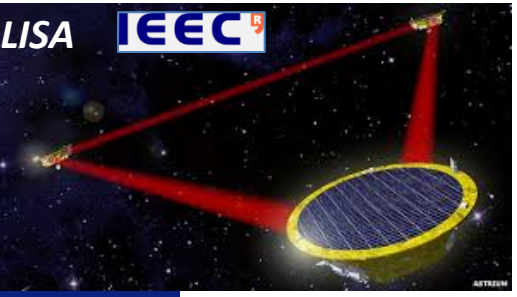
Axion and Dark Matter searches



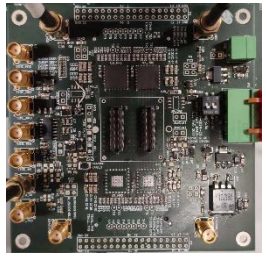
Monte Carlo simulations

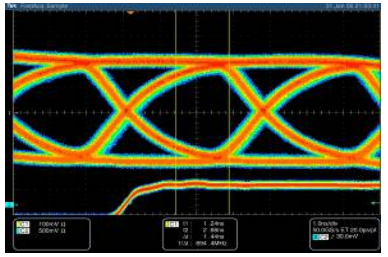


Microelectronics (Chip Design)

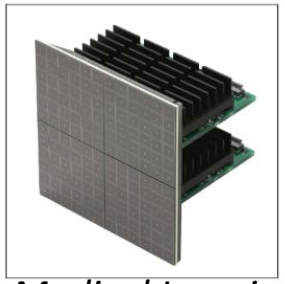


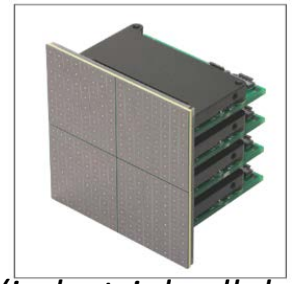
Space missions





Electronics





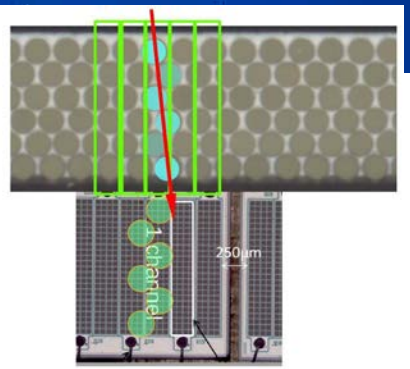
Medical Imaging (industrial collab.)

esa European Space Agency

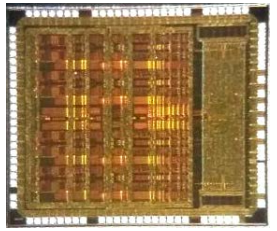
ICCUB Institute of Cosmos Sciences — Excelencia María de Maeztu

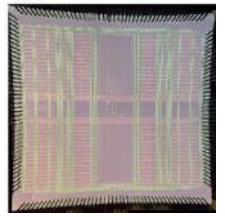
Expertise and main achievements

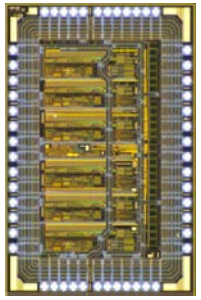
- Our main R&D activities are on:
  - Single Photon Sensors
  - Integrated readout electronics (ASICs)
- Main achievements:
  - Readout of LHCb calorimeters and SciFi trackers
    - Photosensor selection and optimization with industry
    - ICECAL and PACIFIC ASICs
      - PACIFIC in collaboration with IFIC, Univ. Heidelberg and LPC
  - Cameras of LST and MST telescopes of CTA
    - Optimization of photosensor for single pe resolution at very low gain
    - Three different ASICs: PACTA, ACTA and L0 triggers
  - Scientific and industrial collaborations with industry
    - SiPM modules for ToF-PET
- More than 50,000 produced for LHCb and CTA
  - Quality control of mass production with a robotic system developed in-house

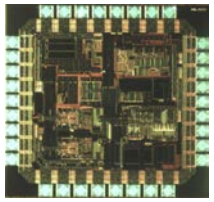


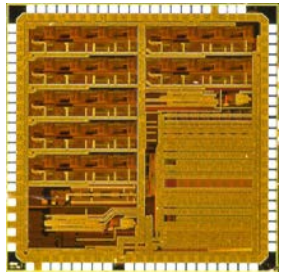
SciFi (LHCb)

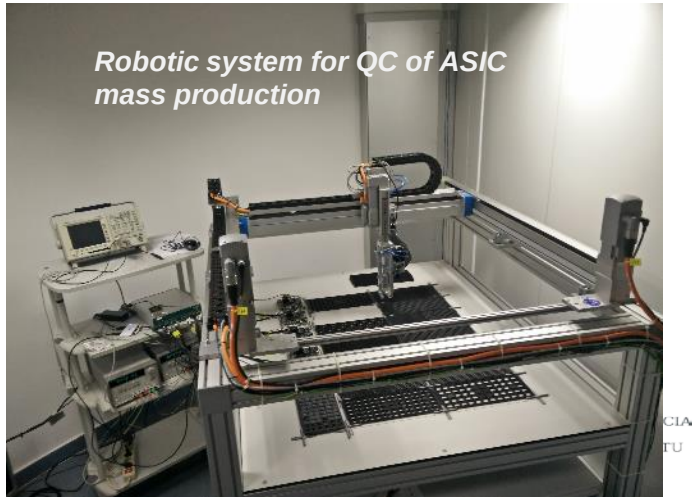

ICECALv3 (LHCb)


PACIFIC (LHCb)


ACTA (CTA)

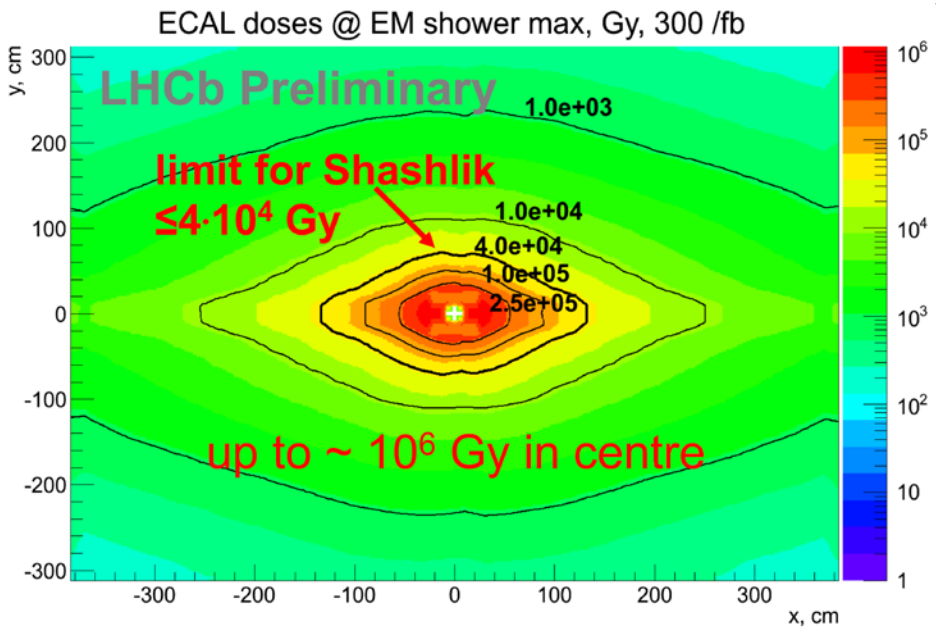

PACTA (CTA)


L0 Trigger (CTA)

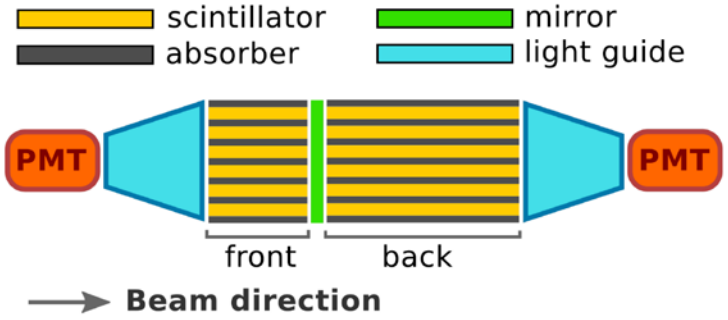


DRD: LHCb ECAL Upgrade II

- Calo upgrade II for LHC LS4
  - Replace inner modules with new radiation hard technology
  - Picosecond timing:
    - Optimized light generation and collection
    - Dual side readout
    - New photosensors
    - New FE electronics

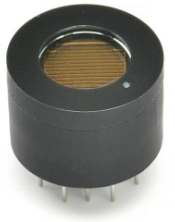


- SpaCal-W prototype module
  - Pure tungsten absorber with 19 g/cm^3
  - garnet crystal fibers
  - 9 cells of 1.5x1.5 cm^2 (RM ≈ 1.45 cm)
  - 4+10 cm long (7+18 X_0)
  - Reflective mirror between sections

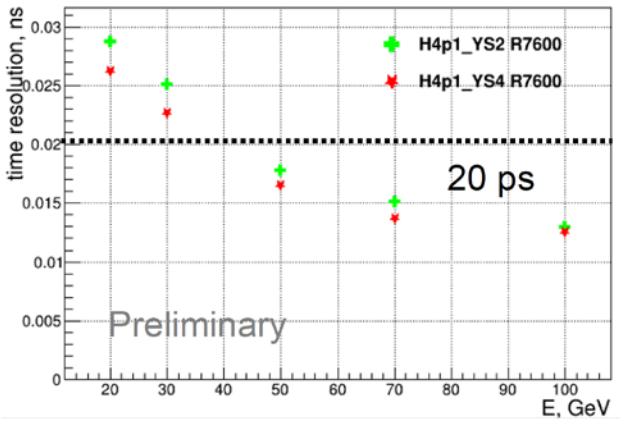


R11187 (TILECAL), R7600U-100

R14755U-100

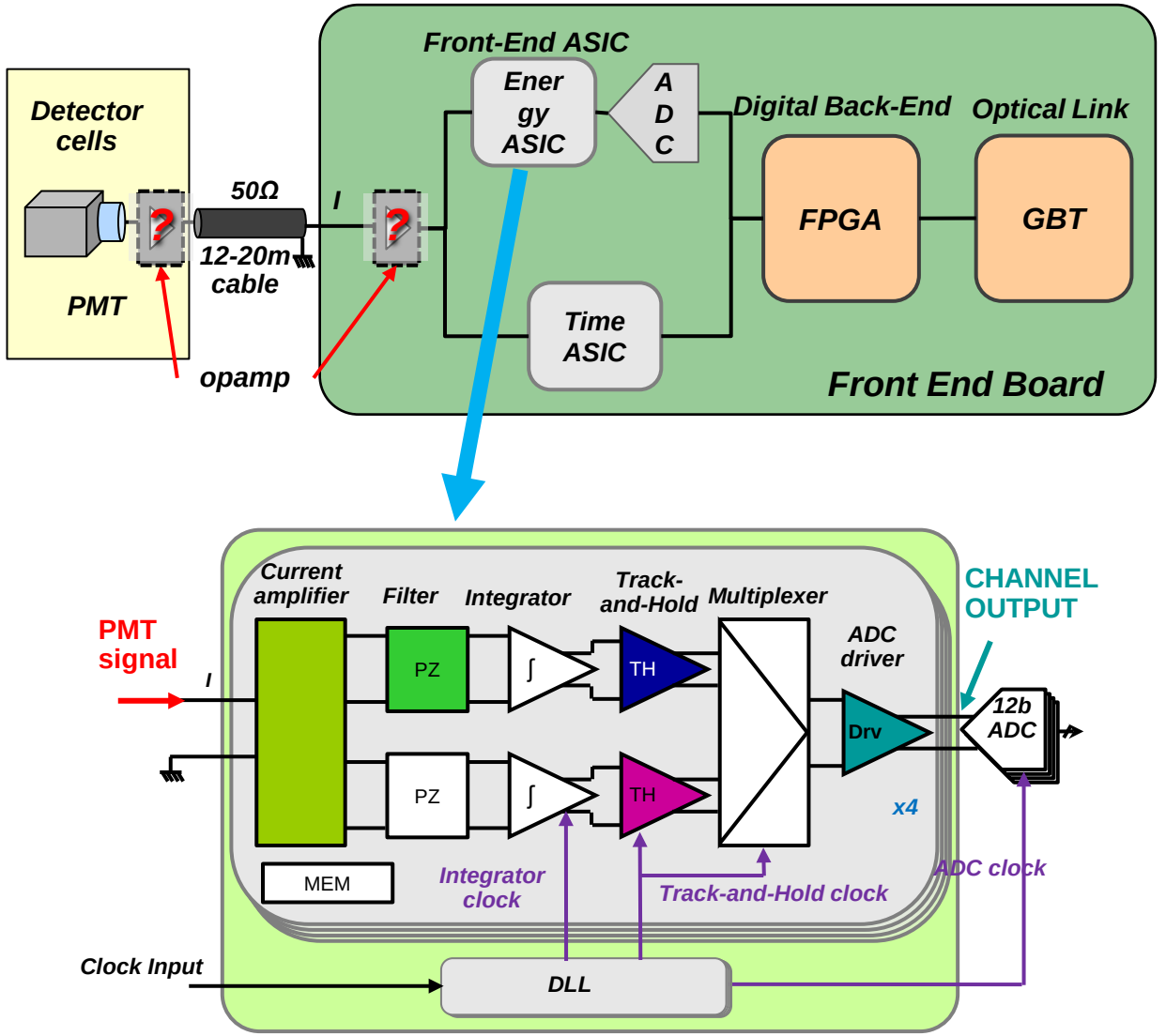


Double-sided readout (CERN SPS 2021



DRD: LHCb ECAL Upgrade II readout electronics

- ASIC/chipset in TSMC 65nm with separate energy and timing processing paths
- Amplifier + Shaper circuit included on the PMT base or FEB under consideration to compensate cable attenuation, improve SNR, if necessary, and reduce spill-over effort
- Energy path ASIC
  - time-interleaved double channel scheme for integrator recovery
  - dynamic range: more than 15 bits (bigain)
  - fully differential to improve noise rejection,
  - Internal digitization is under consideration



Collaboration with IFIC, UPC, several IN2P3 groups (IJCLAB, LPC,…) and CERN

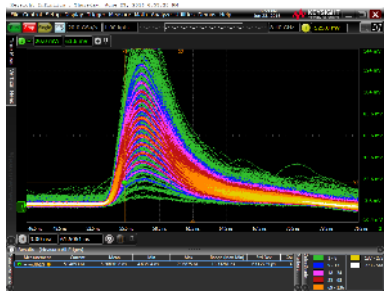
Funded by PID2019-106448GB-C31 (FPA)

ICCUB

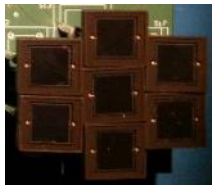
DRD: solid state cameras for Cherenkov Telescopes

- Current MST and LST cameras are based on PMTs
- SST cameras and upgrades for MST and LST: SiPMs
- We have started R&D for SiPM cameras
  - MUSIC chip

Funded by PID2019-104114RB-C33 (FPA)



7 x SIPM
6x6 mm^2 each



≈

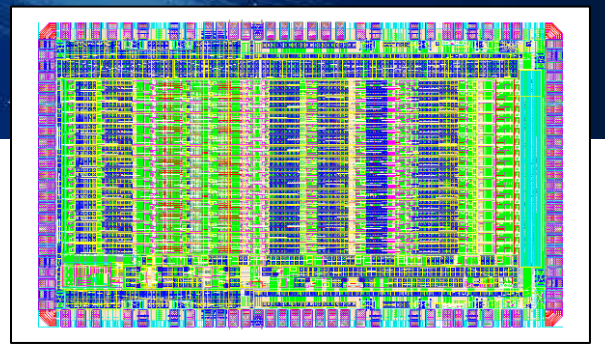
1 x PMT
18 mm diameter

Other applications, e.g.
SHiP, ToF detectors

Collaboration with IFAE, UPC and University of Geneva

ICCUB

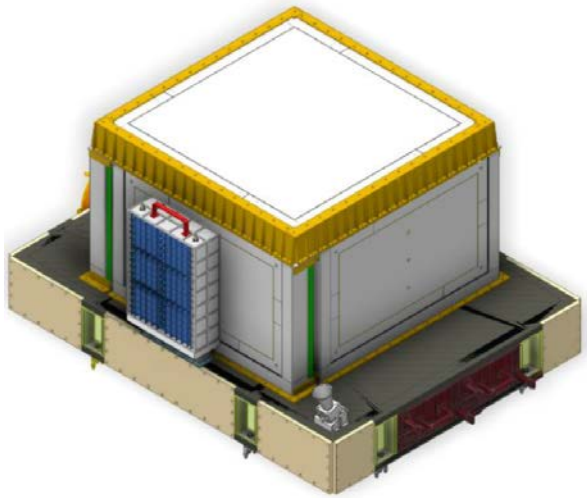
DRD: detectors for space applications

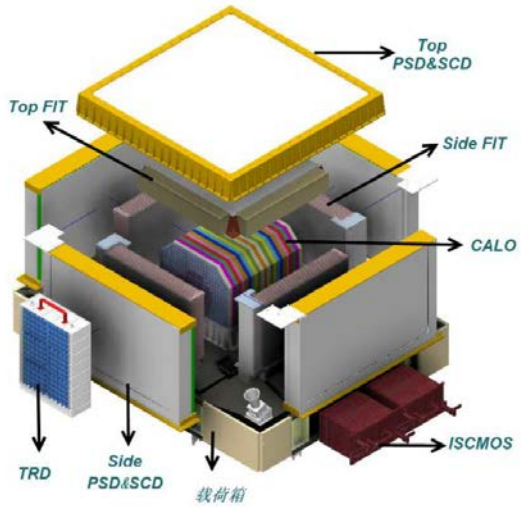


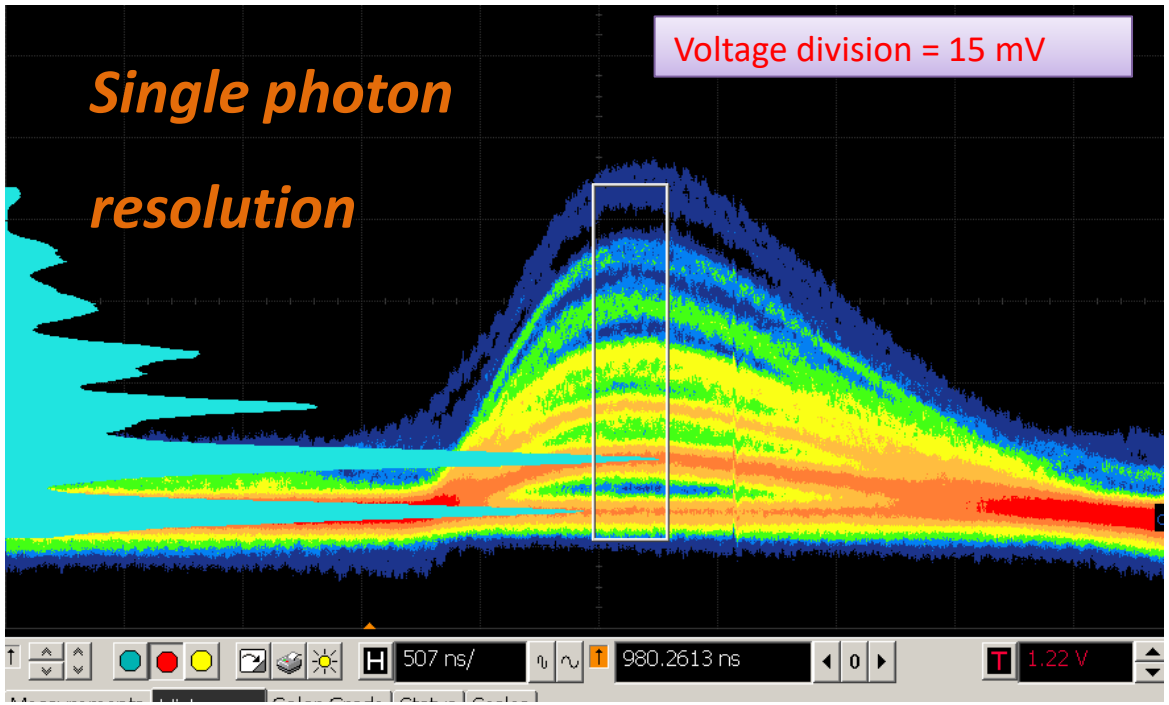
BETA ASIC for multiple space applications: fiber tracker, calorimeter, ToF, RICH, scintillators..

- ✓ Channels: 16 (FIT version: 64 ch)
- ✓ Event rate : 10 kHz max
- ✓ Configurable preamplifer gain: 4 bits
- ✓ Tunable shaping time: 230 ns to 1.5 us
- ✓ Trigger output: < 250 ps time resolution
- ✓ Single photon resolution: SNR >10
- ✓ Dual path: automatic gain switching
- ✓ On chip ADC: Wilkinson11 bit + 1bit (path sel)
- ✓ Dynamic Range : 15 bit
- ✓ Slow Digital Control : I2C
- ✓ Power Budget : <1 mW/ch

16 ch - 130 nm CMOS – 7 mm^2







HERD is a flagship scientific experiment on the Chinese Space Station (CSS)

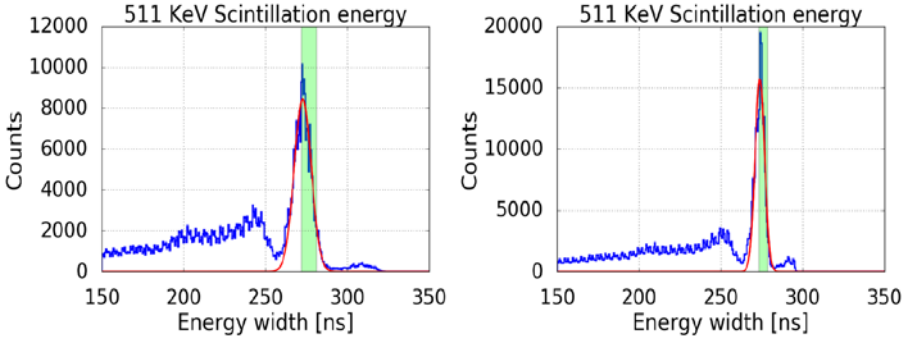
Funded by PID2020-116075GB-C21 (ESP)

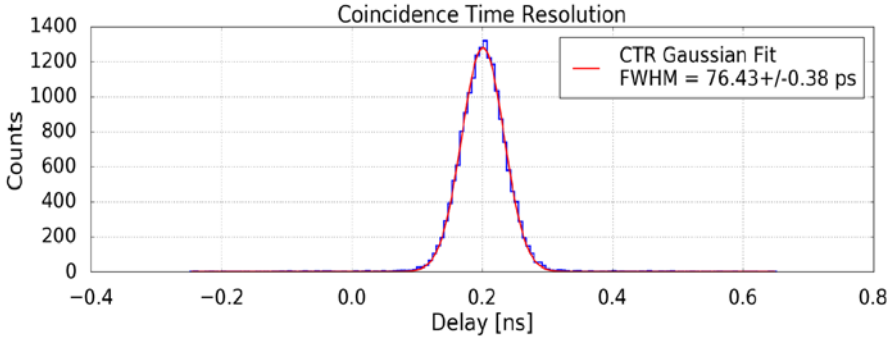
ICCUB
Institute of Cosmos Sciences

DRD: FastIC Front End ASIC

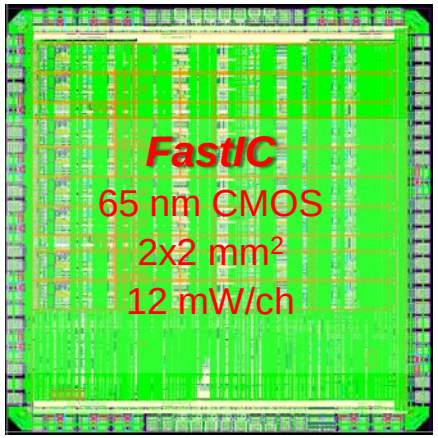
- **FastIC** current mode FE ASIC
  - Applications in HEP (RICH, ToF) and industry (medical imaging, LIDAR, etc)
    - Example: PDC2021-121442-I00 (FPA)
- Readout of sensors with intrinsic gain
  - SiPMs, PMTs, MCPs
- New version with embedded 25 ps TDCs
  - **FastIC+**
- A dedicated version for LHCb RICH upgrade
  - **FastRICH (LS3)**

- **Sensor:** FBK-NUVHDLFv2b 3x3 mm², 40 pixel pitch.
- **Crystal:** LSO:Ce Ca 0.2% of 2x2x3 mm³.

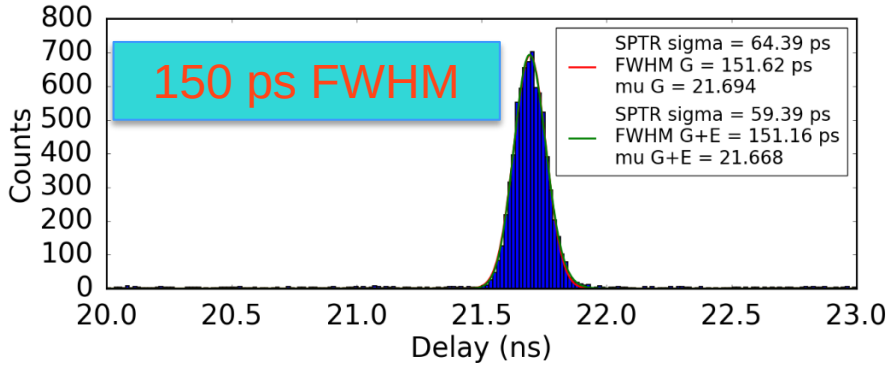




CTR = 76 ps FWHM



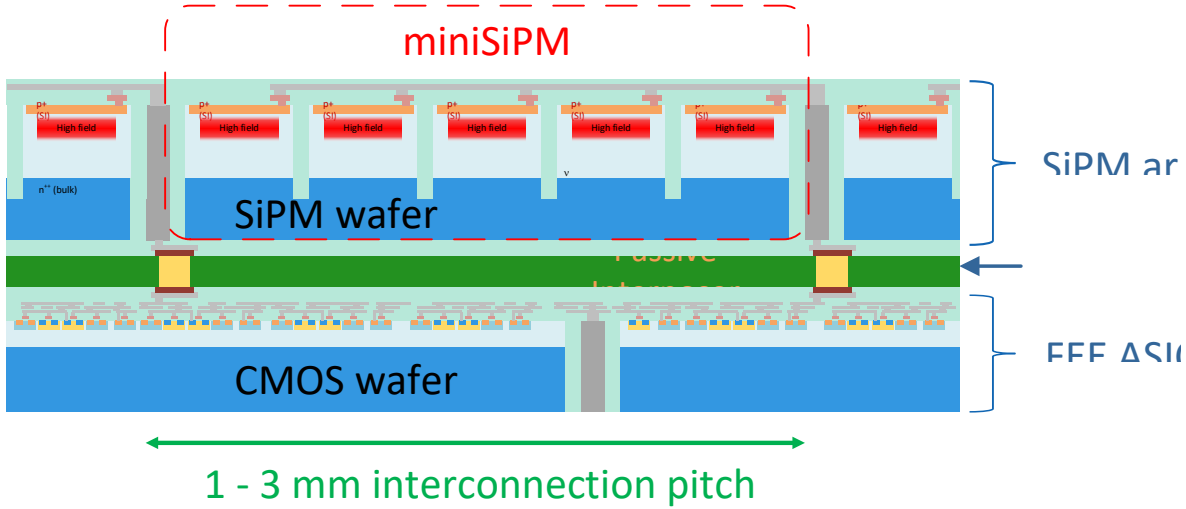
SPTR with FBK-NUVHDLFv2b 3x3 mm²



Collaboration of the ICCUB (Univ. Barcelona) and CERN-MIC

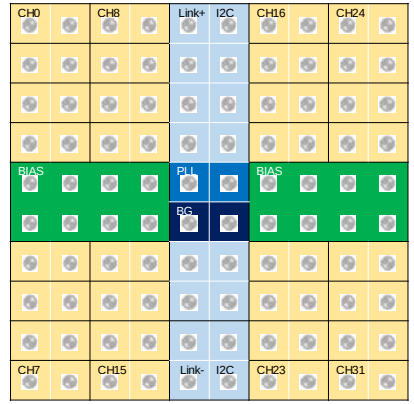
DRD: towards a hybrid solid state photosensor for ps timing

- 2.5D and 3D Integration
  - Photon Detection Module (PDM) in which SiPMs with TSVs down to 1 mm pitch
  - Connected to the readout ASIC on the opposite side of a passive interposer
- Goal: exploit the ultimate SPAD performance at system level
  - 10 ps for single photons

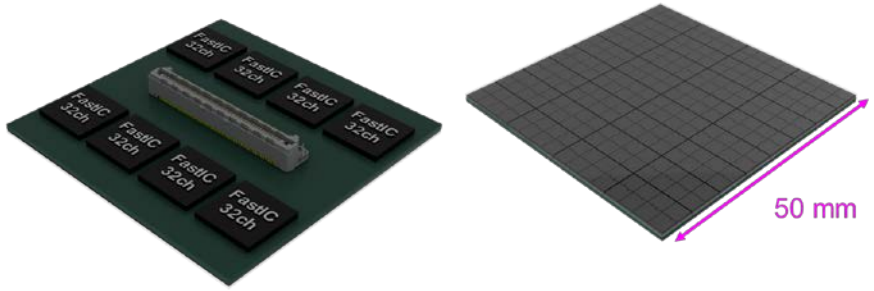


Integrated Photon Detection Module

FastIC 32



First step will be a PDM based on FastIC32:

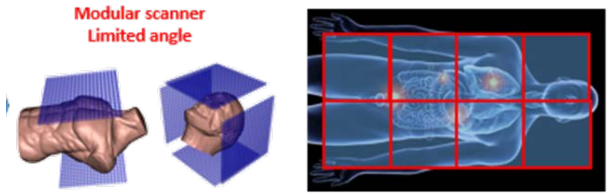


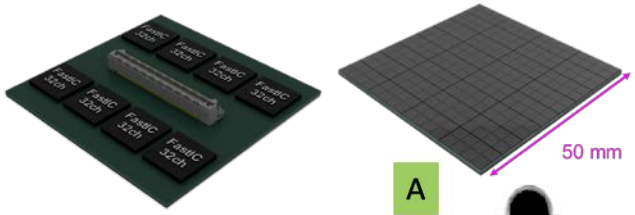
Hybrid SiPM module being developed for ultimate timing performance in ToF-PET

ICCUB Institute of Cosmos Sciences
EXCELENCIA MARÍA DE MAEZTU

DRD: a new ToF-PET scanner concept with solid state PDM

- The **PETVision** Project was approved! Call: **Horizon EIC 2022 Pathfinder-open**.
  - 5-year project starting in September 2023
- The aim of PetVision is to leverage on 3D / 2.5D integration techniques to build a modular ToF-PET scanner, with next-generation performance and affordable cost.



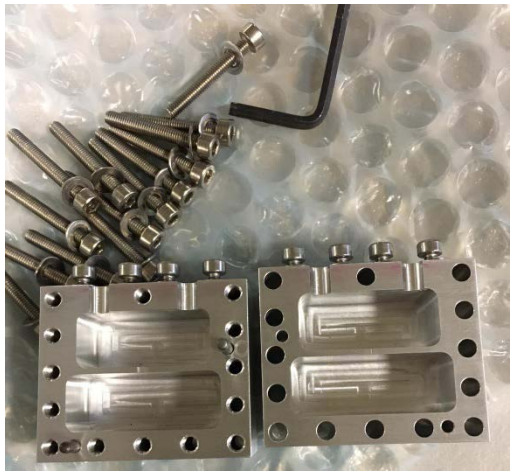


Partner	PI	Country
JSI	Rok Pestotnik	SI
FBK	Alberto Gola	IT
ICCUB	David Gascon	ES
Oncovision	Jorge Alamo	ES
CSIC	Jose Maria Benlloch	ES
TUM-MED	Wolfgang Weber	DE
MGH	Georges El Fakhri	USA

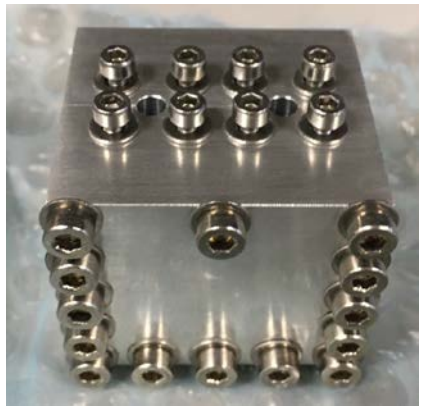
Simulation of the capability of the proposed planar TOF PET imager: Reconstructed Image (3mm slices) of an XCAT digital phantom acquired by two 120x60cm^2 panel detectors (above and below the patient) assuming 100 ps TOF resolution and 10 mm scintillator thickness (A) and with small 4 panel system used to image head (B) and torso (C)

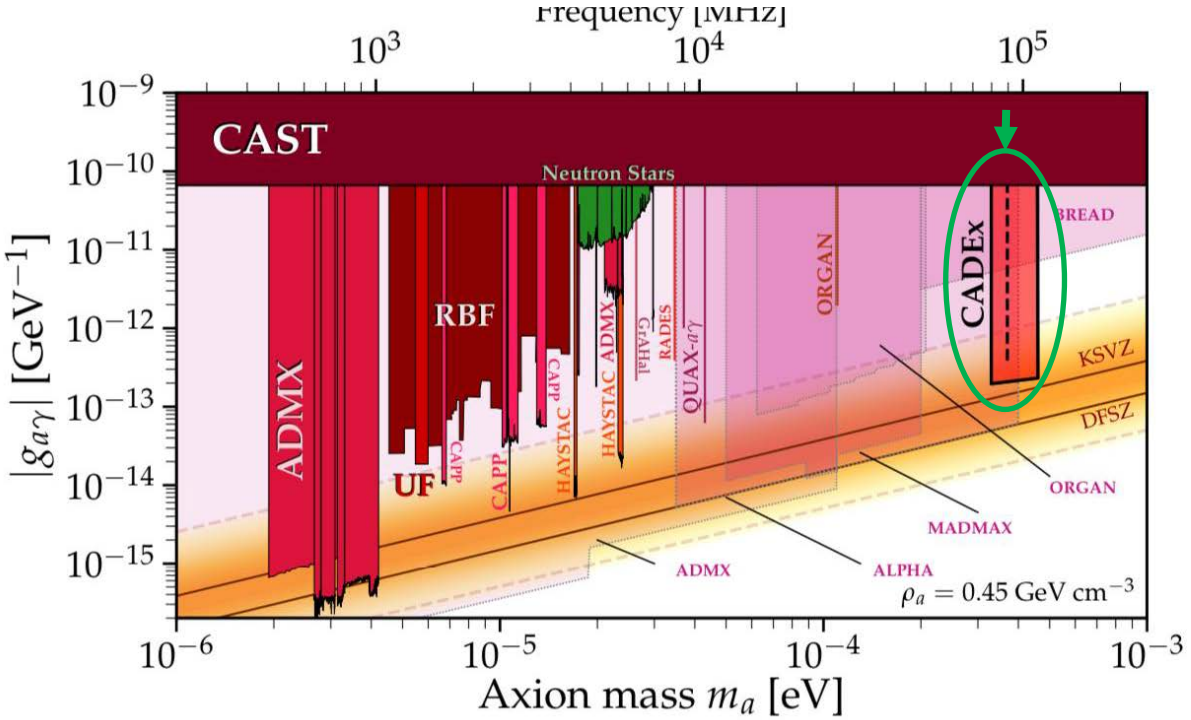
DRD: Axion searches

- ICCUB is involved both in helioscope and haloscope @ IAXO
- R&D on RF cavities
  - RADES collaboration: searches ~8 GHz
  - Experiments hosted at CERN in the past, now planning for LSC, IAXO and others.
  - R&D on detectors based on qubits (Takis Kontos, CNRS/ENS).
  - Also KIDs detectors at 90 GHz in CADEx.



Cavity for qubit





Funded by PID2019-108122GB-C32 (FPA)

Summary

- Our main R&D activities are on:
  - Single Photon Sensors
  - Integrated readout electronics (ASICs)
  - Hybrid solid state photo-detectors based on vertical integration
  - Picosecond detectors and electronics
- For photosensor and readout ASICs there's a strong synergy with
  - DRD3 (Solid State)
  - DRD4 (Photodetectors and PID)
  - DRD6 (Calorimetry)
  - DRD7 (Electronics)
- Personnel involved solid state photosensor and readout ASICs :
  - Faculty (physics and electronics): 4 permanent FTEs
  - Engineers: 5 permanent FTEs
  - Post-doc and non permanent engineers: currently 5 FTEs
- Personnel involved in DM axion searches based on quantum technologies (DRD5):
  - Faculty: 1 FTE
  - Engineers: 1 FTE

Thanks a lot for your attention !!!

http://icc.ub.edu/technology

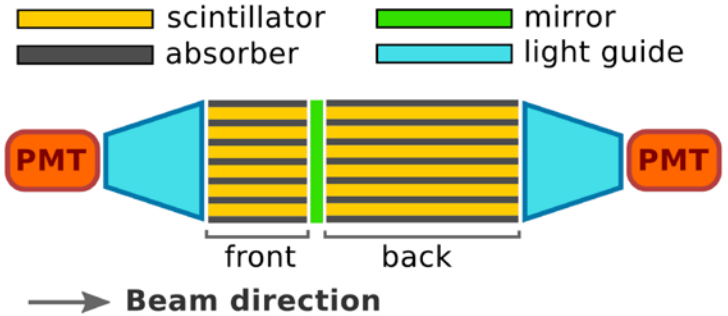
Thanks a lot for materials and contributions to our colleagues !!

dgascon@fqa.ub.edu

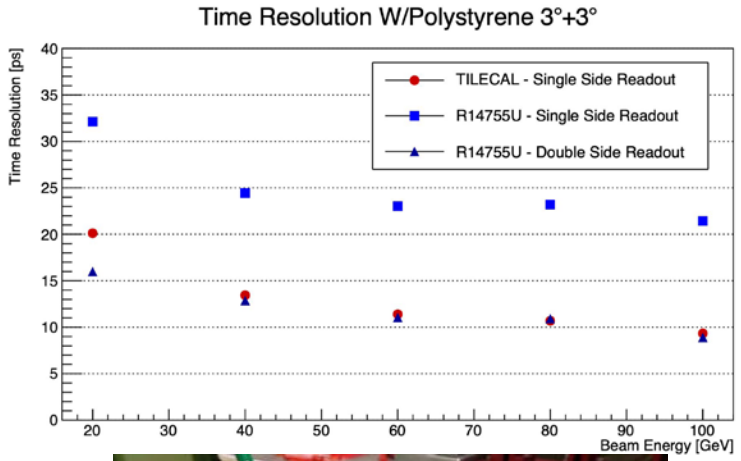
DRD: LHCb ECAL Upgrade II

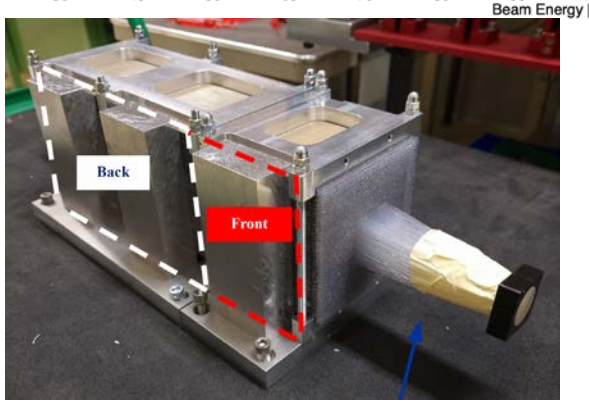
SpaCal-W prototype module

Pure tungsten absorber with 19 g/cm^3
garnet crystal fibers
9 cells of 1.5x1.5 cm^2 (RM ≈ 1.45 cm)
4+10 cm long (7+18 X_0)
Reflective mirror between sections

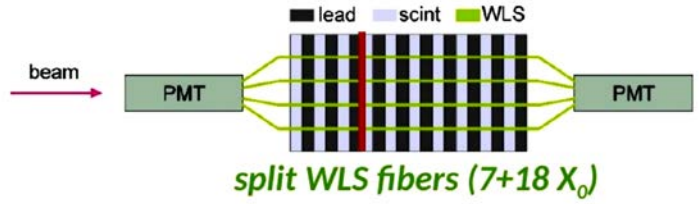


- **SpaCal-Pb prototype module**
  - Pb absorber + polystyrene fibers
  - 9 cells of 3x3 cm^2 (RM ~ 3 cm)
  - 8+21 cm long (7+18 X_0)
  - Reflective mirror between sections
  - Kuraray SCSF-78 fibres (1mm)





- **Shashlik prototype**
  - in outer part of ECAL and provide timing information
  - Split WLS fibers (7+18 X0, mirrored fiber ends)
  - Kuraray WLS YS2 and YS4



Double-sided readout (CERN SPS 2021