# FOCAL PAD R&D

*Marco van Leeuwen, Nikhef, UU*
*on behalf of the FOCAL collaboration*

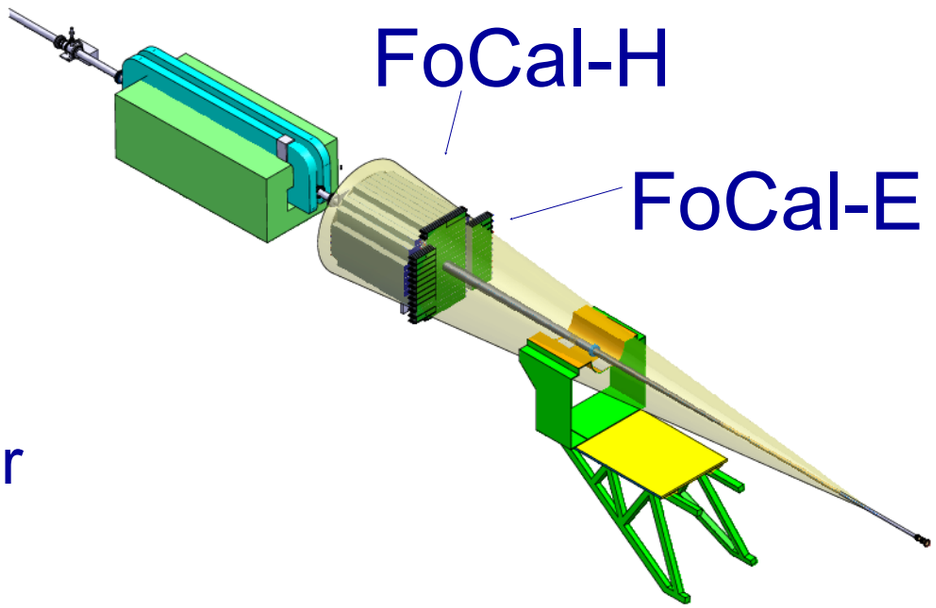
# The FOCAL proposal

$3.2 < \eta < 5.3$

(baseline design @ 7m)

**FoCal-E**: high-granularity Si-W calorimeter for photons and $\pi^0$

**FoCal-H**: hadronic calorimeter for photon isolation and jets

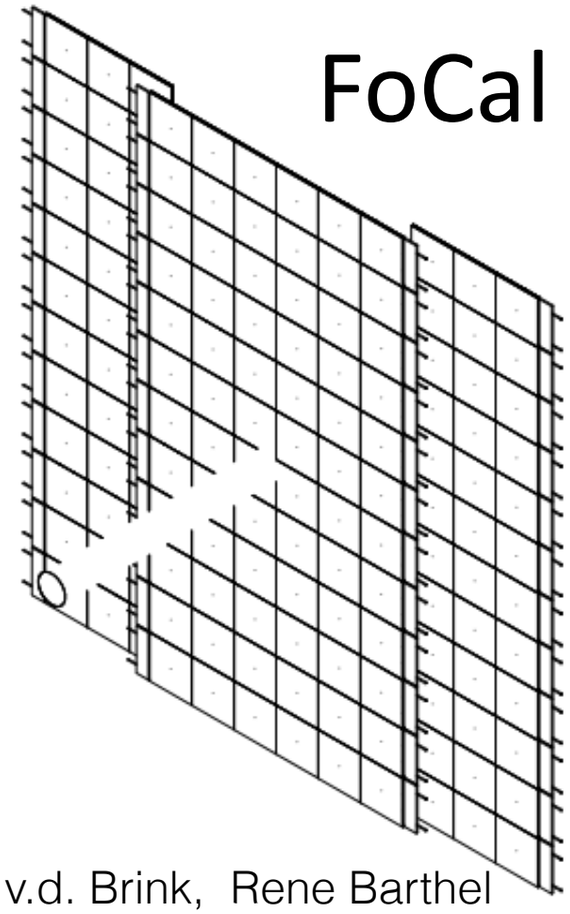



Observables:

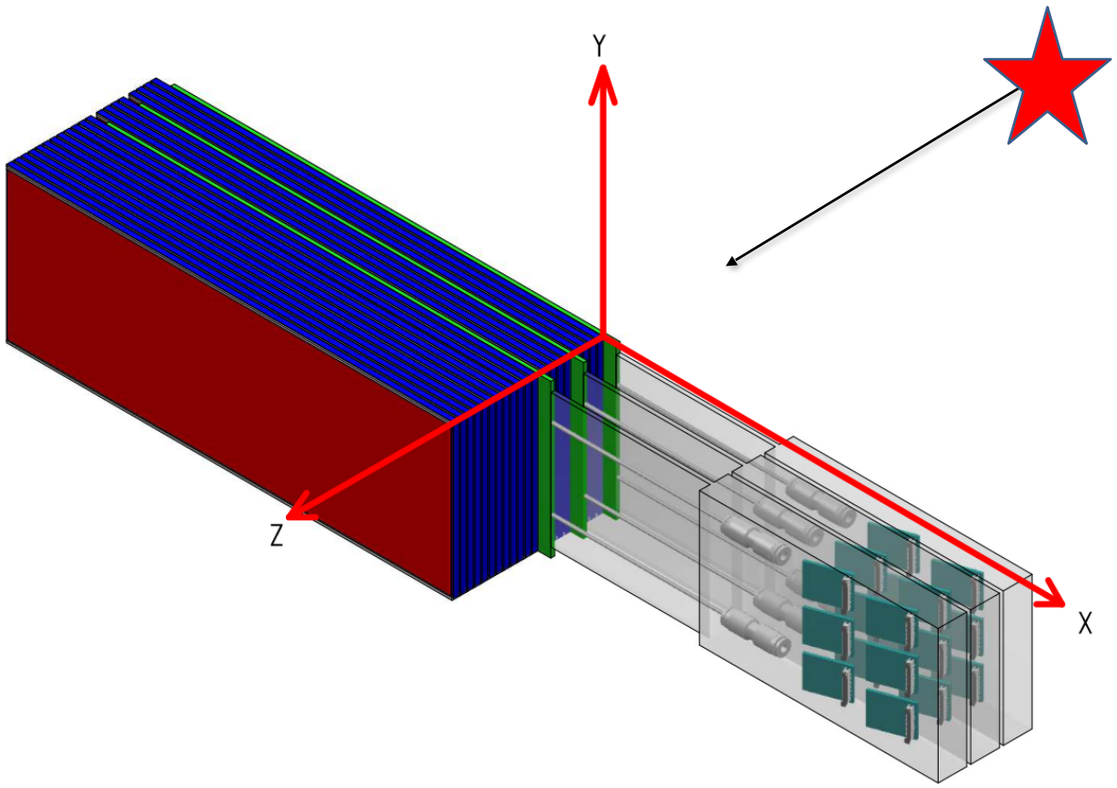
- $\pi^0$
- Direct (isolated) photons
- Jets

Advantage in ALICE:
forward region not instrumented;
'unobstructed' view of interaction point

# FOCAL-E design concept




Ton v.d. Brink,  Rene Barthel

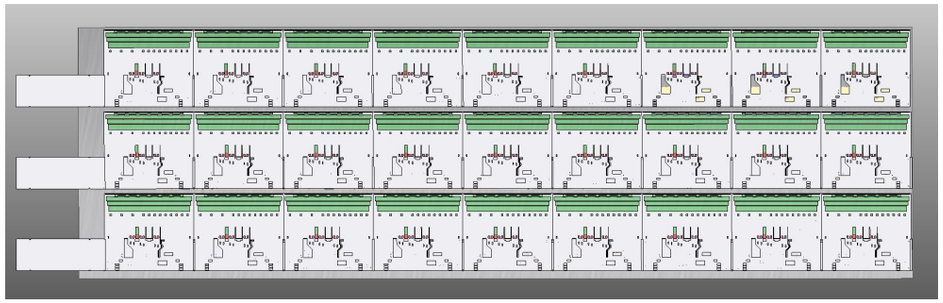



Goal/idea: build modules with 3 ‘towers’
Minimize gaps between towers
Stacked vertically into ‘slabs’

PAD layers
+ pixel layers for position resolution

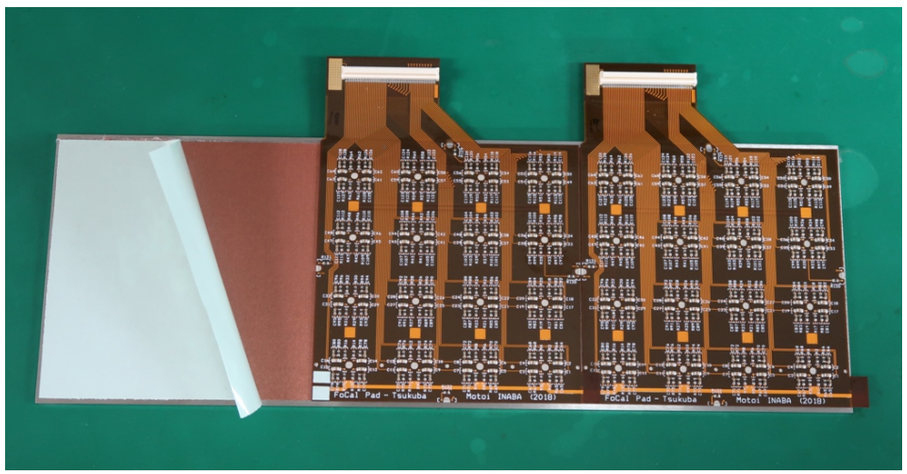
# Overall conceptual design is settled/understood

## Layout concept for pixel layer



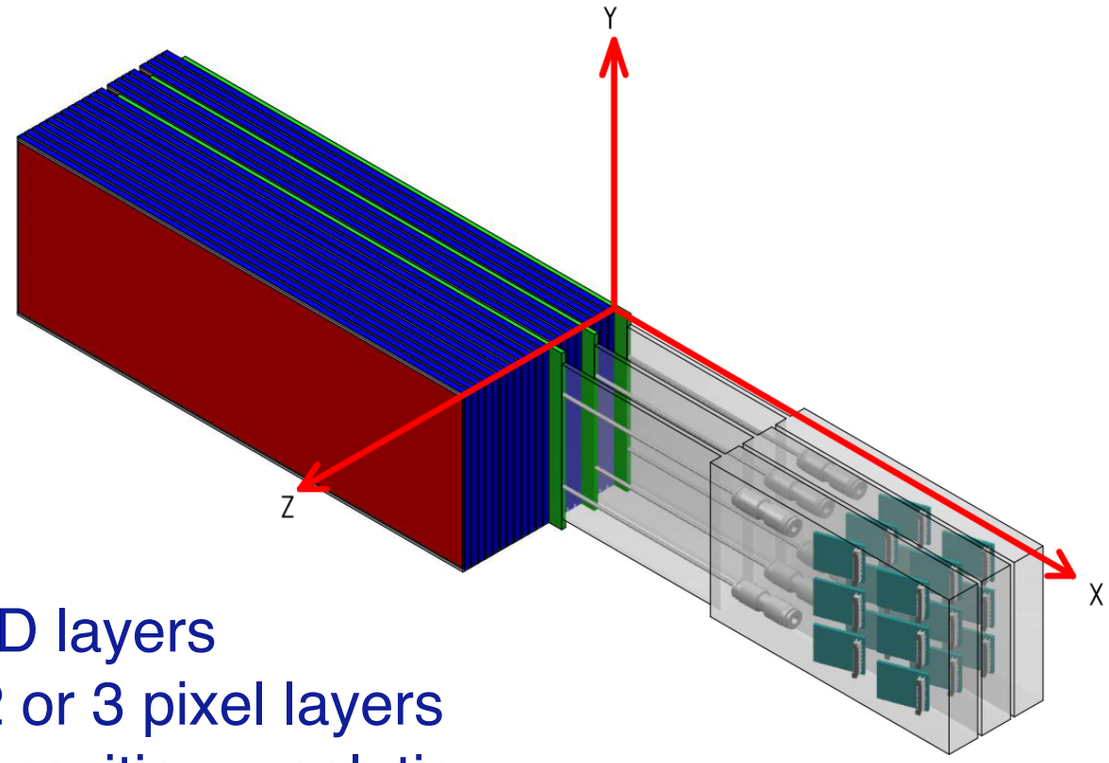
6x9 ALPIDE sensors (2 or 3 layers)

## PAD module prototype




3 sensors: ~9x8 cm

FoCal module: ~28x8 cm




PAD layers
+ 2 or 3 pixel layers
for position resolution

Services/connections
to 1 side for integration

# PAD readout requirements

- Large dynamic range: 1 MIP to 2 TeV
  - 3 fC - 5 pC
- Good linearity/precision
  - Aim to achieve 1% energy resolution at high end; need few per cent resolution per pad
- Rate: expect to read out at up to 1 MHz in pp, p-Pb
  - Can be untriggered; event selection in HLT
  - LHC: 40 MHz bunch spacing
- Radiation: expected load 100-1000x smaller than ATLAS/CMS; does not seem to be critical

# Options for PAD readout ASIC

Two approaches: ADC+TDC (HGCROC) or two ADCs with dual range setup

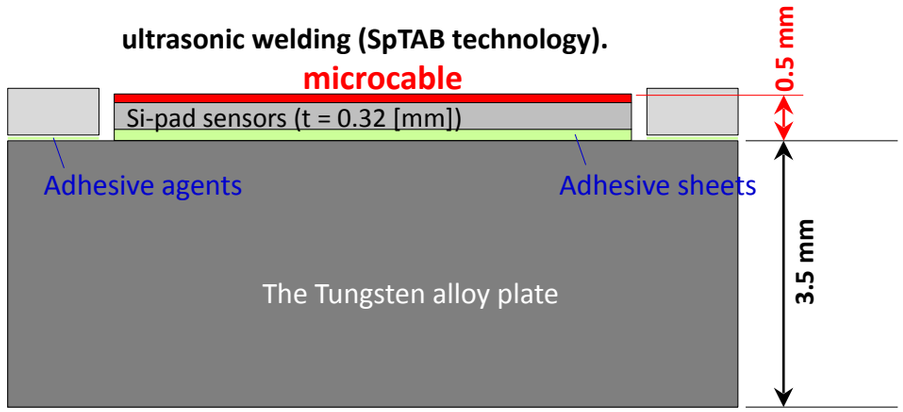
- HG-CROC:
  - Under development by CMS for this purpose; time line tight
  - ADC for small signals ( < 100 MIP) + TDC for large signals
- SAMPA
  - Developed for ALICE TPC, MUON arm; available
  - Would need dual-range readout with attenuation
- VMM
  - Developed for ATLAS ‘small wheels’; a version is available, not fully tested
  - Would near dual-range readout with attenuation

Still under discussion; several options pursued in parallel

# Design question: Distance between W layers

## Distance between layers dictated by placement of electronics

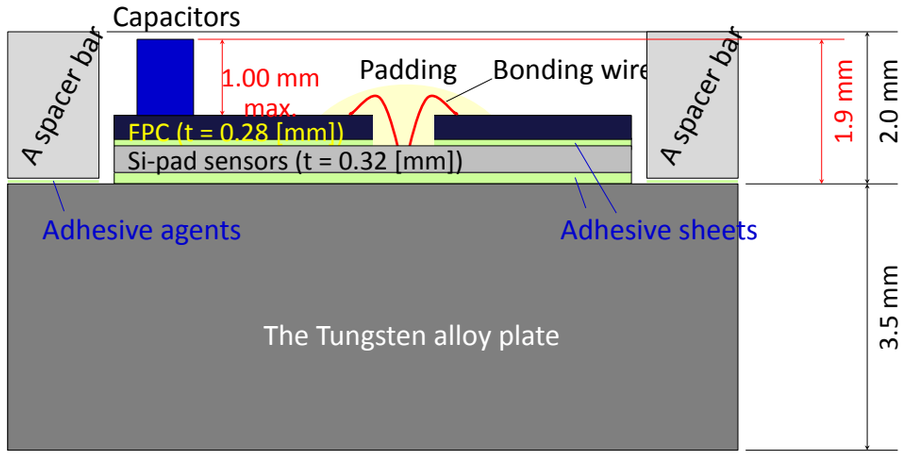
### Electronics outside layer


Advantage: compact detector, small Molière radius, good spatial resolution

Disadvantage: long signal cables; risk of noise, cross-talk

### Electronics inside layer


**Current PAD protype**

Advantage: shorter signal paths; good signal integrity

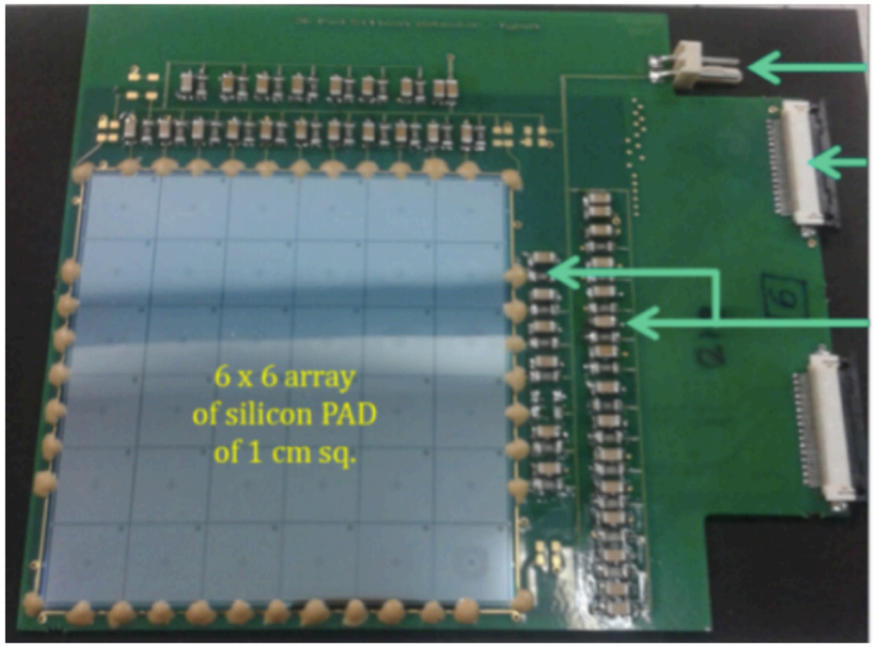
Disadvantage: worse spatial resolution; cooling may be challenging

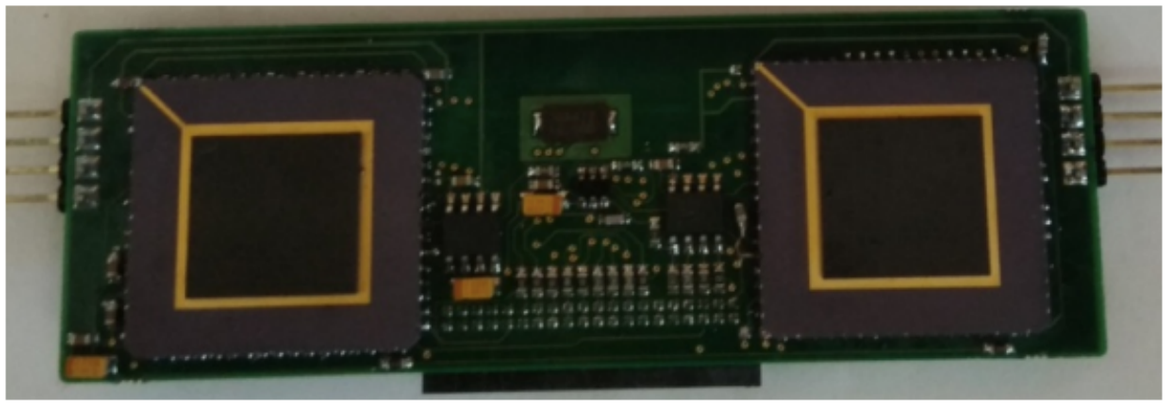
Expect effect on Molière radius, two-shower separation

Performing simulations to understand the effect

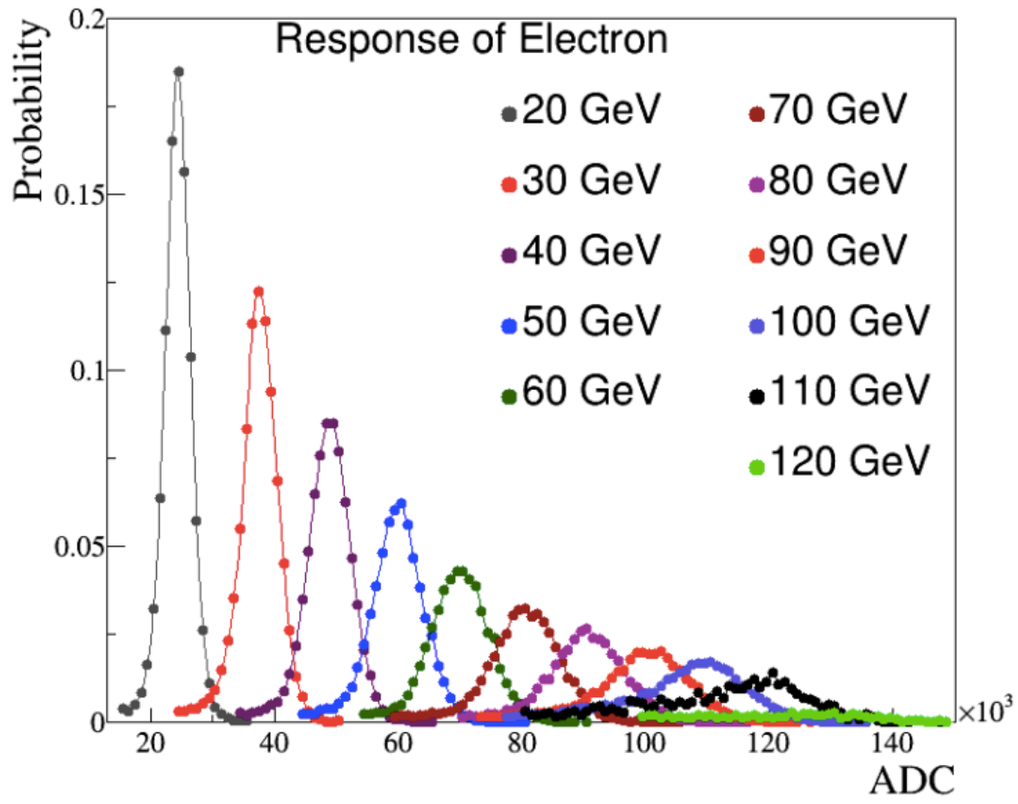
# PAD prototypes

## Activity in India: VECC, Kolkata and BARC Mumbai



Pad sensor and analog readout development: ANUINDRA



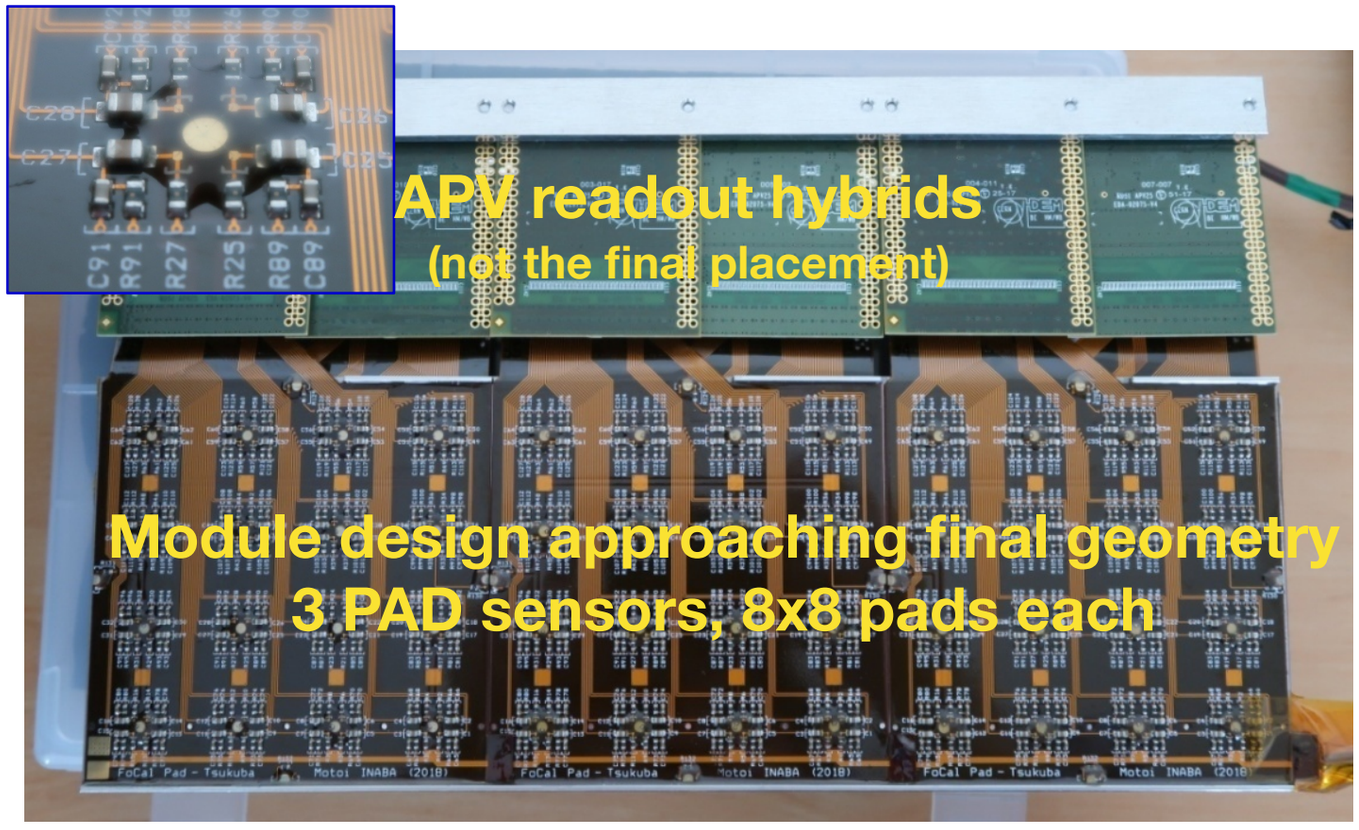

Large dynamic range achieved

Resolution under study

Challenge: pad-by-pad calibration/response

# PAD Prototypes

## Pads connected to flex PCB

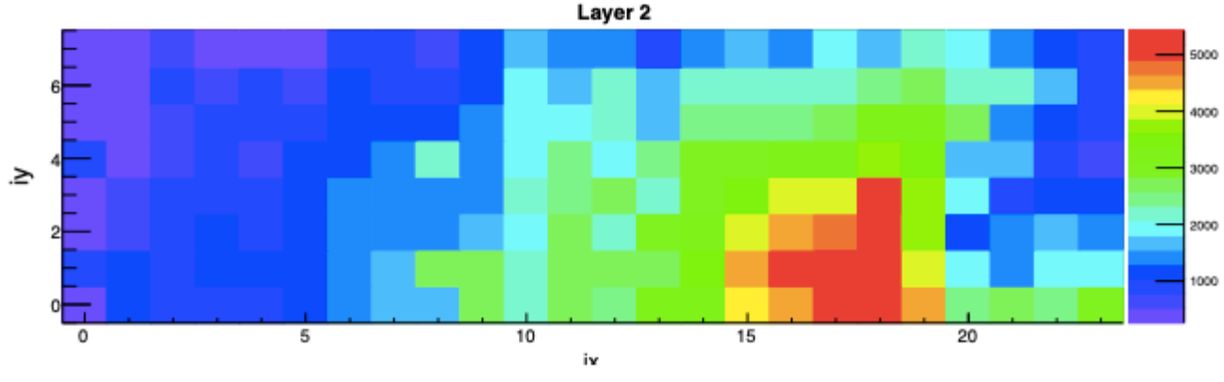



## Large activity in Japan (Tsukuba)

Several test runs; design approaching final geometry

Pad sensors: Hamamatsu
Readout: currently APV (limited range)
testing new readout options

## Hit Map from test run in ALICE



# Summary/conclusions

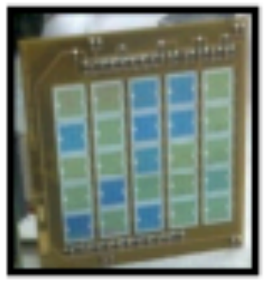
- FOCAL conceptual design: pad + pixel sensors
- Pad sensor and readout development ongoing
- Test beam to finalise design, test performance
  - Results being analysed
- Various solutions for ASIC under consideration:
  - HGCROC
  - SAMPA
  - VMM
- Design question: inter-layer distance and effective Molière radius
  - Under study

# Thank you for your attention

# Pad sensor and readout development

## Silicon Pad Detectors

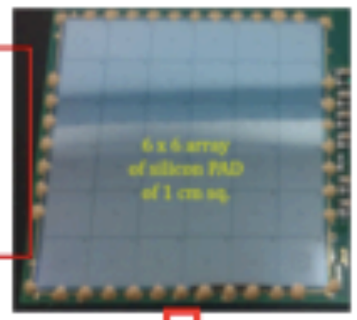
Physically Isolated



2012

5 x 5 array

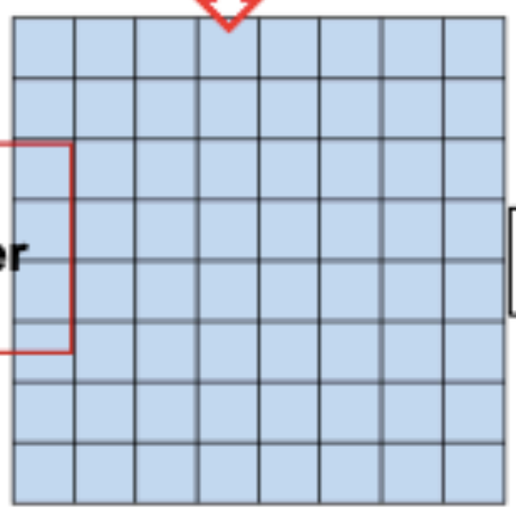
On a Single wafer (4 inch)




2015 & 2017

6 x 6 array

On a Single wafer (6 inch)



Proposed for 2018

8 x 8 array

## ASIC Development

+500 fC to -300 fC

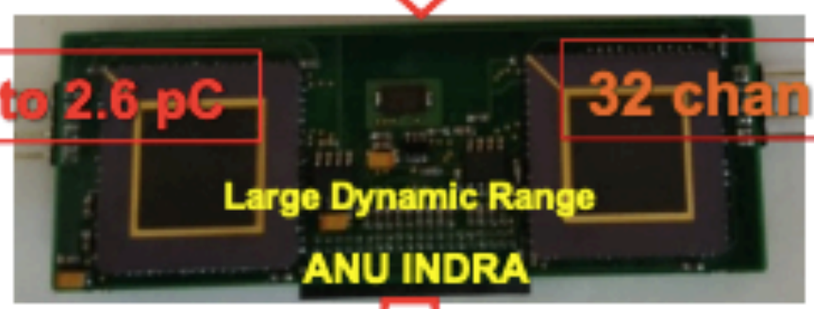
64 channel


+600fC to -600 fC

32 channel


2.4 to 2.6 pC

32 channel

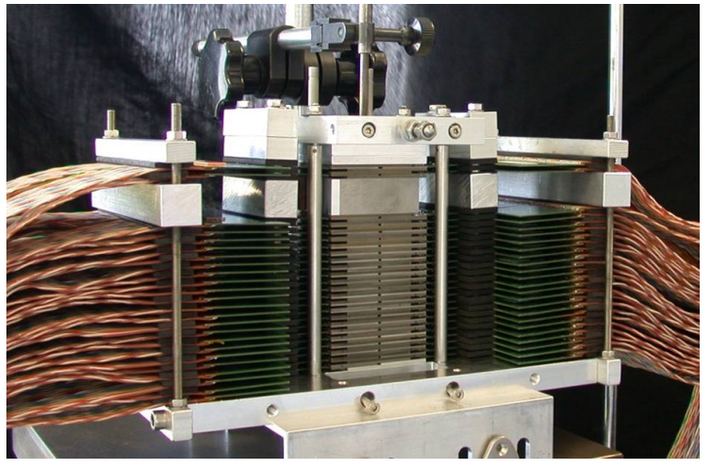



1000 MIPs

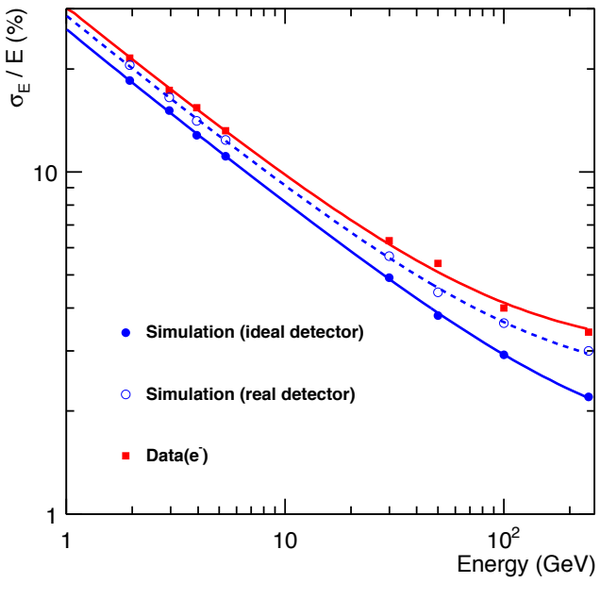
?? channel

# PIXEL prototypes

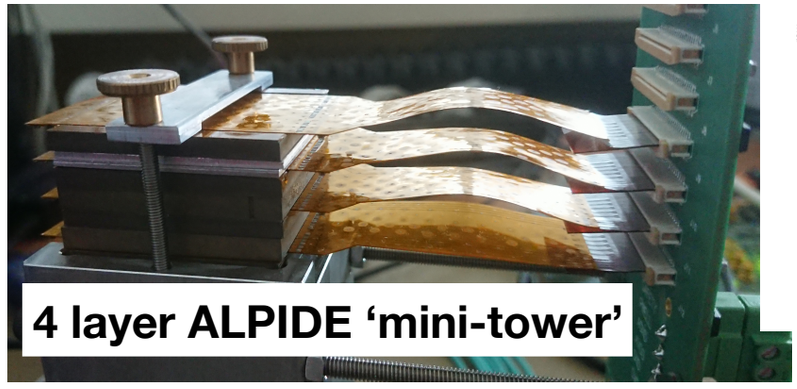
## Full pixel - MIMOSA tower

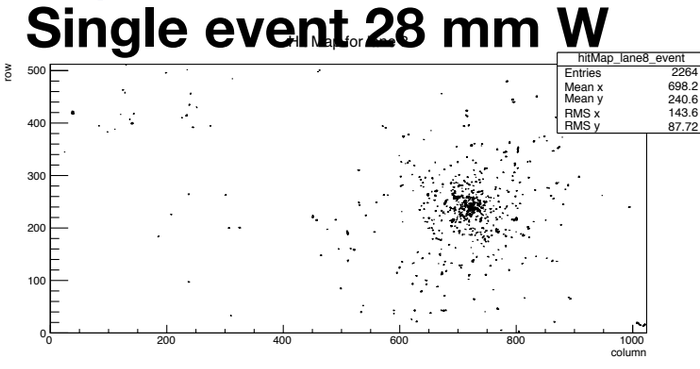


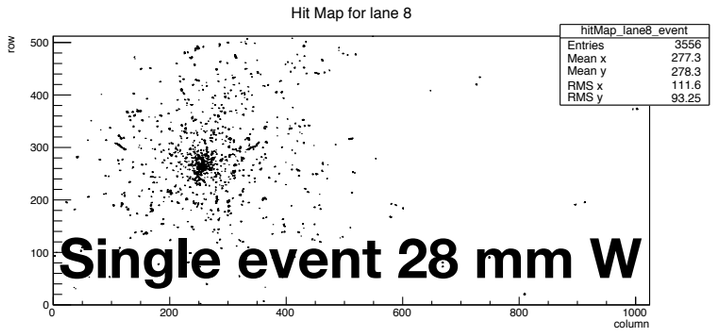
39M pixels




## ALPIDE developments

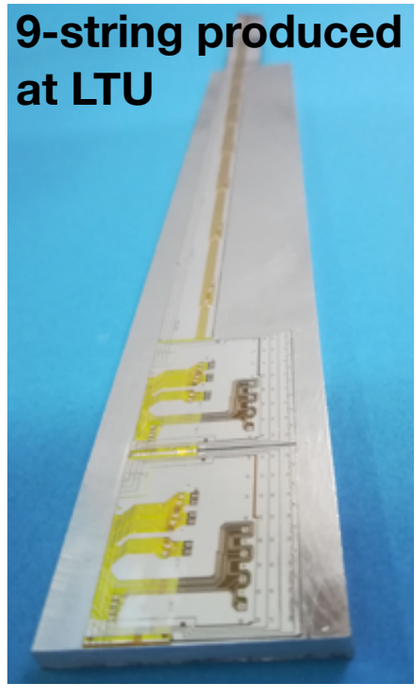



Energy resolution:

$$\frac{\sigma}{E} = \frac{30}{\sqrt{E(GeV)}} + \frac{6.3}{E(GeV)} + 2.8$$

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