Some thoughts on instrumentation at HE-LHC and/or FCC-hh

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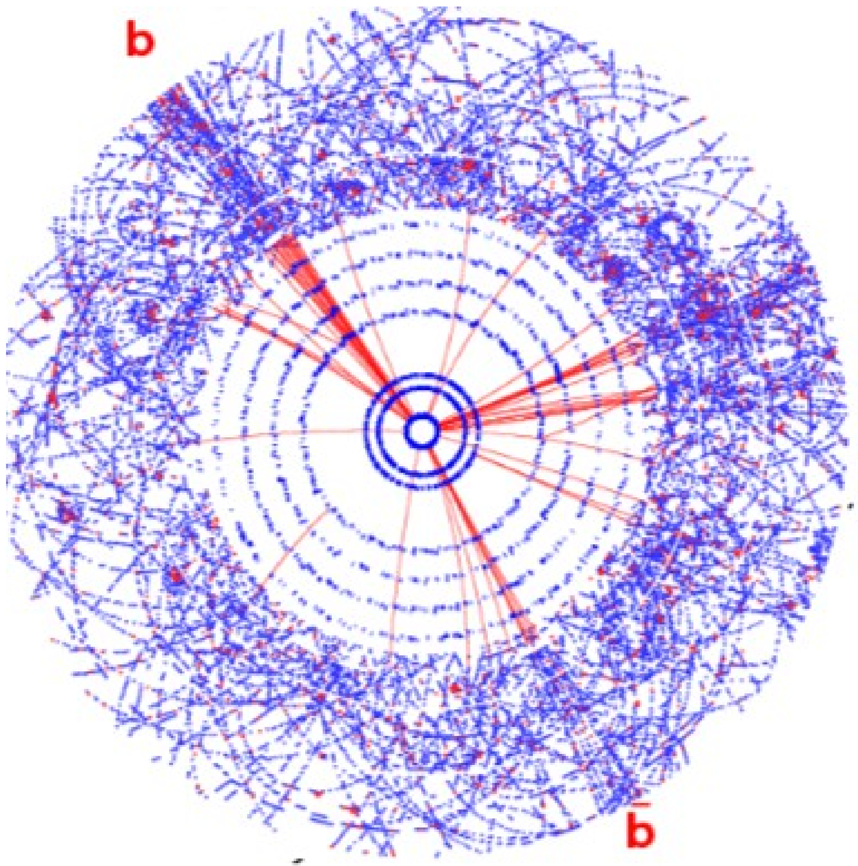
JT Grands Accélérateurs – March 2018

Collider detectors – Basic facts

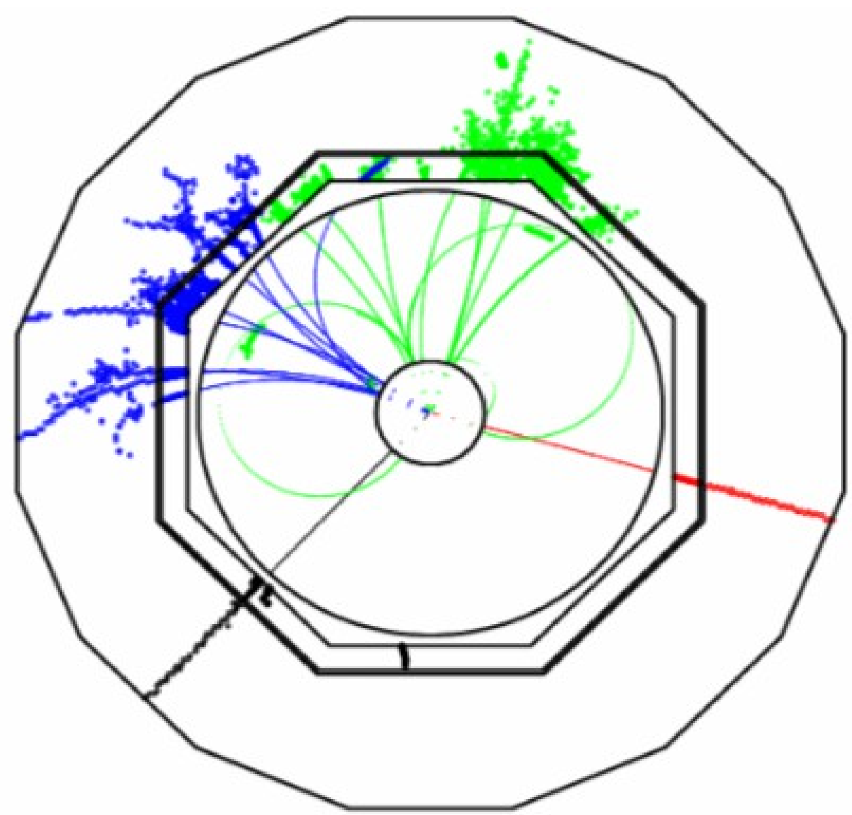
Refondation des Labos
CSNSM - IMNC - IPNO - LAL - LPT

Hadron-hadron collisions
e.g. LHC



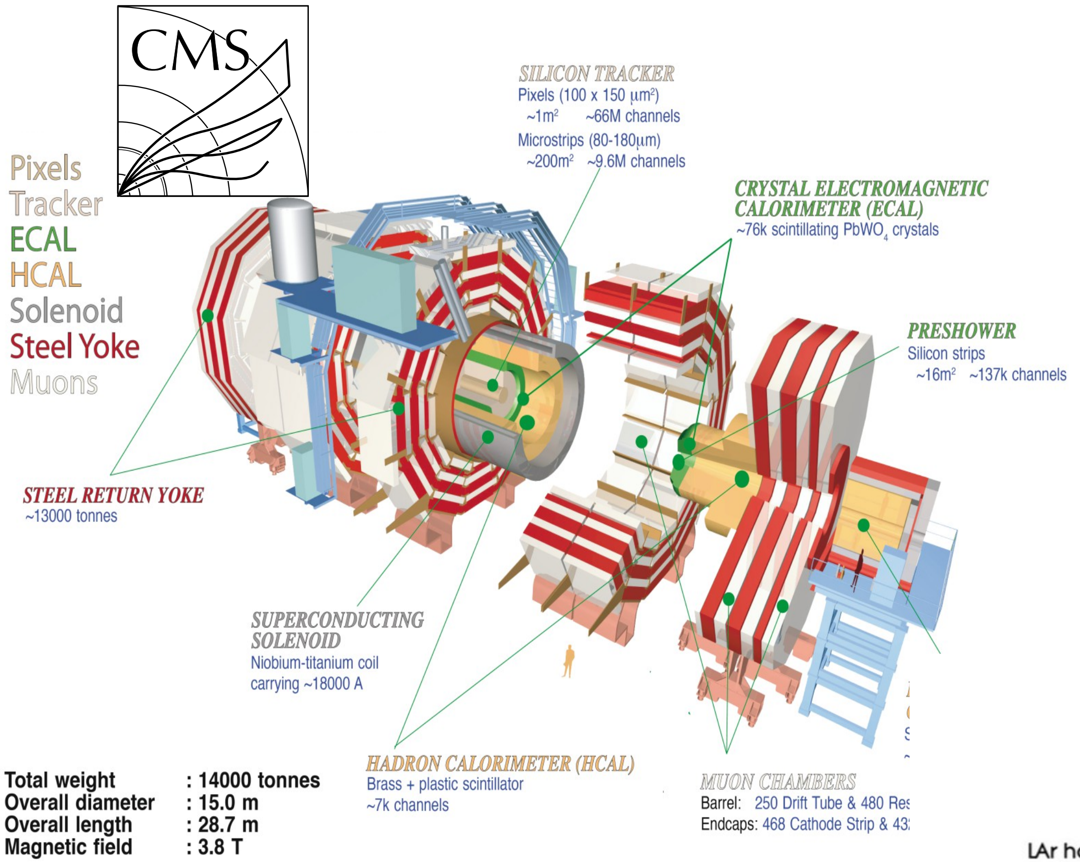
- Busy events
- Requires clean filtering
  Hardware and software

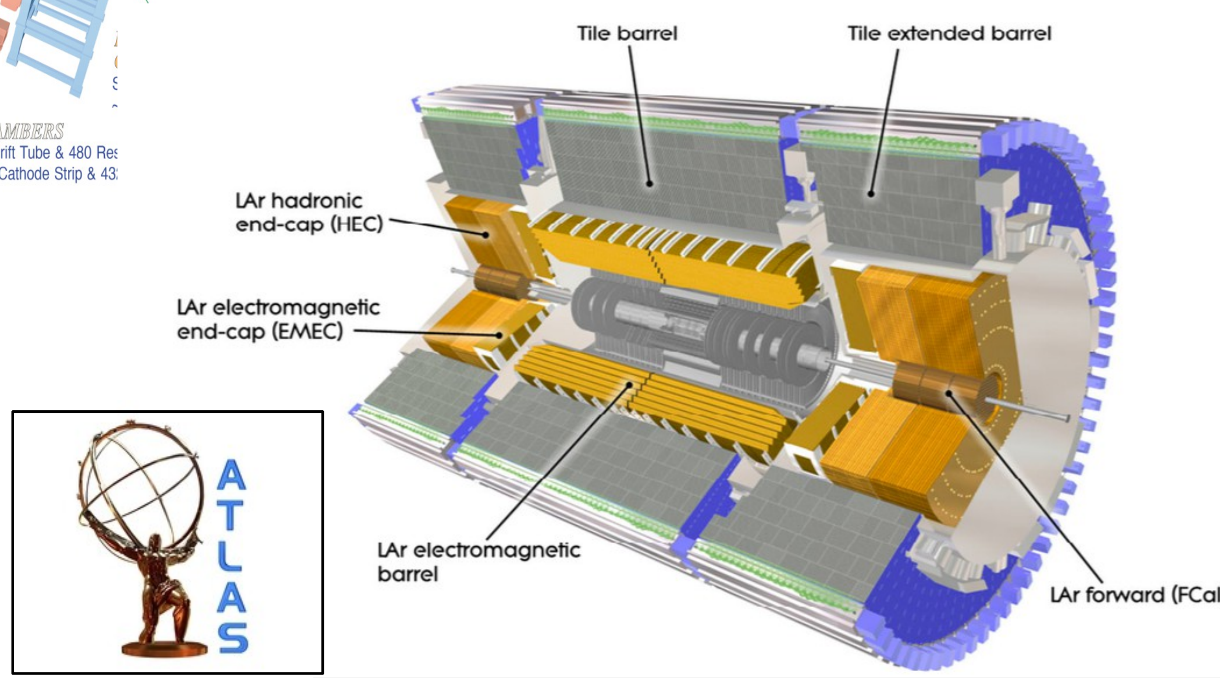
e+e- collisions



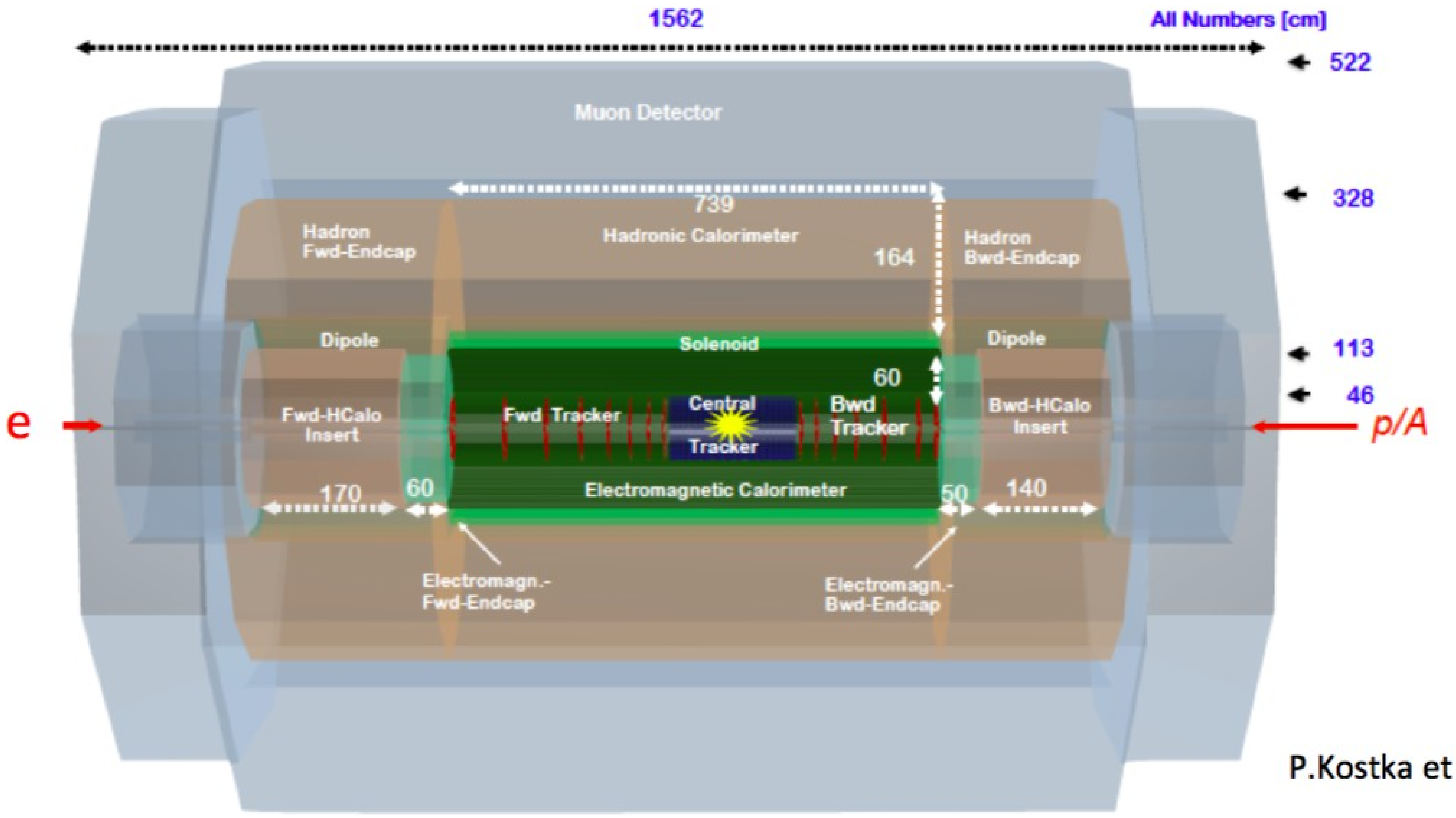
- Clean events
- Full event reconstruction

Detector systems – hadron colliders





Detector systems – ep colliders



P.Kostka et al

Length x Diameter: LHeC (13.3 x 9 m^2) HE-LHC (15.6 x 10.4) FCCeh (19 x 12)

ATLAS (45 x 25) CMS (21 x 15): [LHeC < CMS, FCC-eh ~ CMS size]

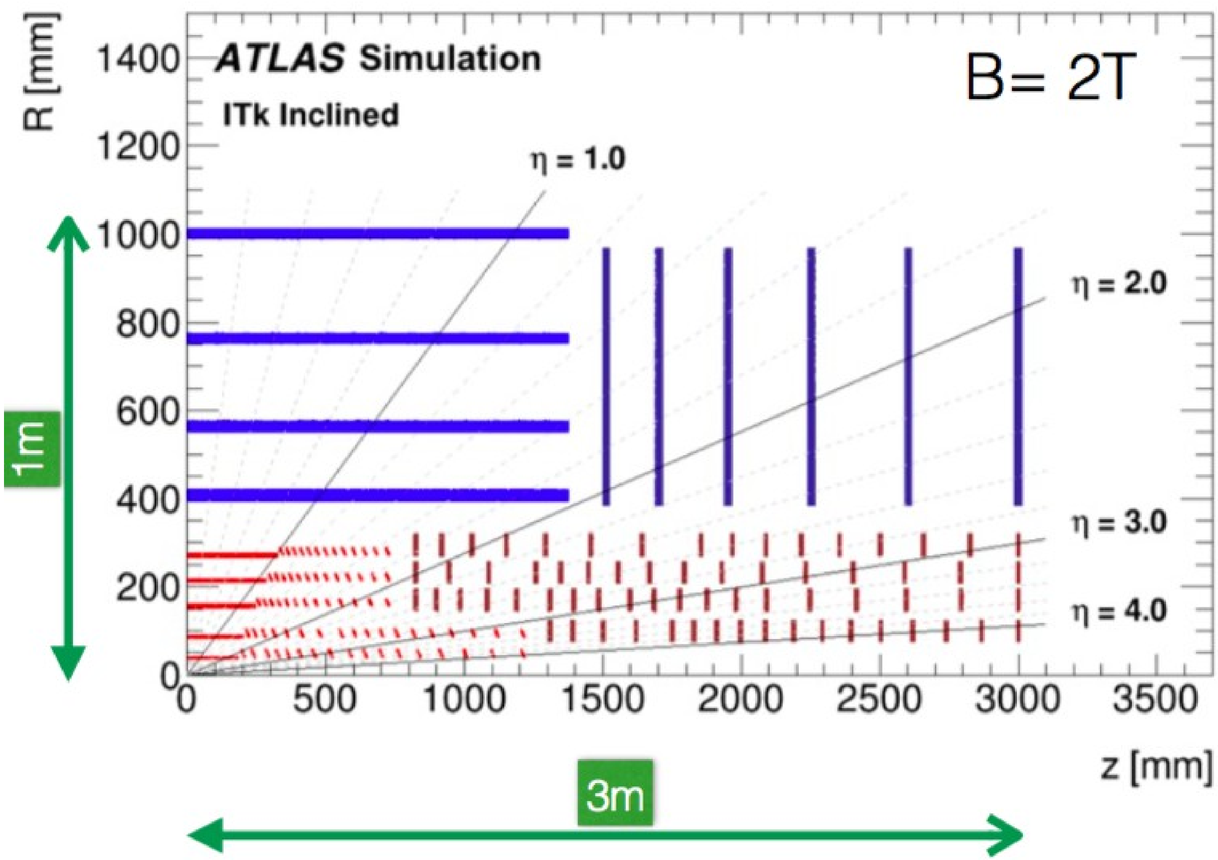
If CERN decides that the HE LHC comes, the LHeC detector should anticipate that

Asymmetric detector that shares features with pp-detectors

ATLAS ITK – See talk by Abdenour

Refondation des Labos
CSNSM - IMNC - IPNO - LAL - LPT

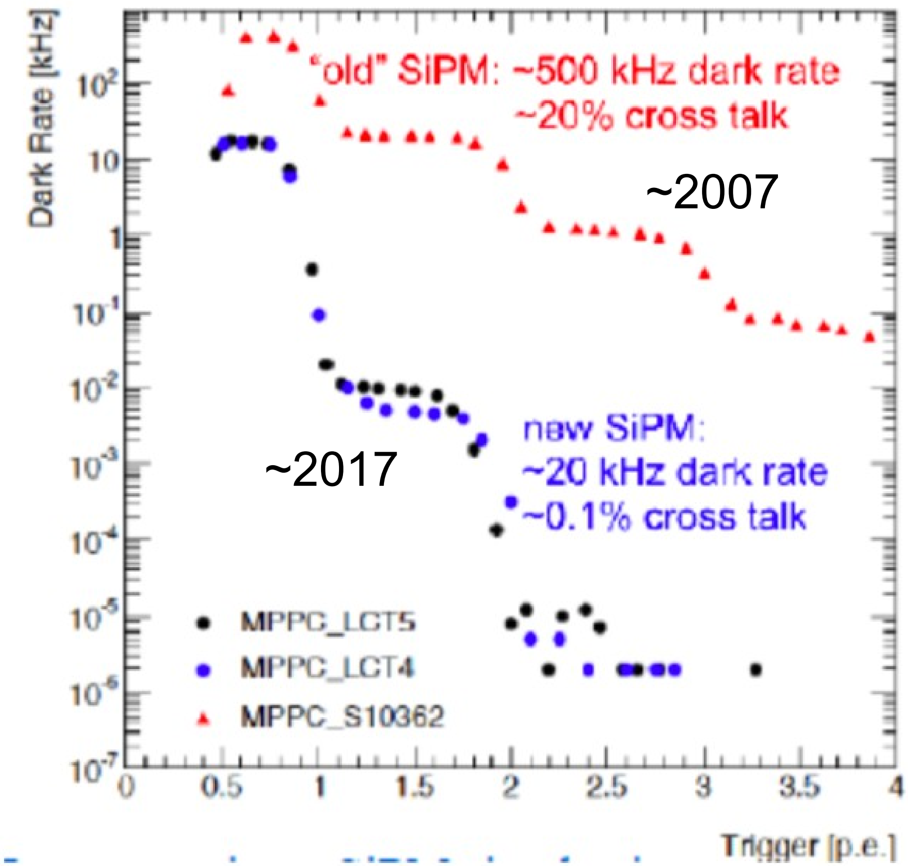
Design goal: ITk should have the same or better performance as the current detector but in the harsher environment of the HL-LHC

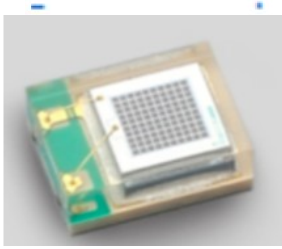


- All silicon design
- η coverage increased to 4 (ID ~2.5)
- **Pixel**: 5 barrel layers (short barrel + inclined modules) + ring disks
- **Strip**: 4 barrel layers + 6 endcap rings

How should ATLAS-ITK-FCC-hh look like?

Readout of "modern" calorimeters I - Optical



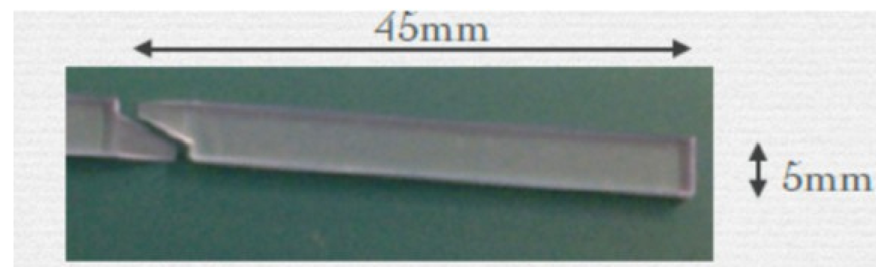


Huge step in quality of SiPM in last decade

- ~Since 2003 MePHI/Pulsar (RU)
- ~Since 2006 Hamamatsu
- Recently Chinese producers

Silcion photomultipliers have many applications Inside and outside of particle physics

- Calorimeters for future e+e- colliders
  Tile Hcal, Dual readout,
  Scintillator Ecal

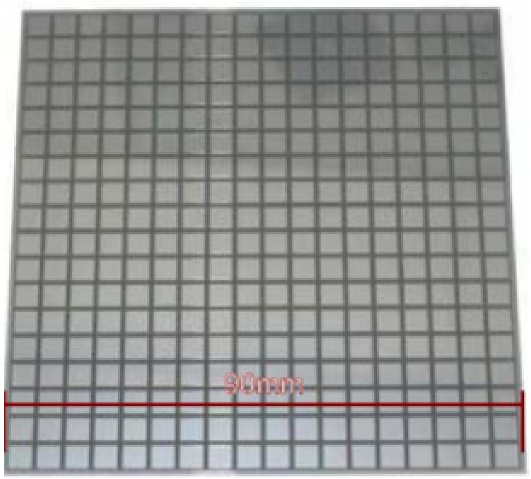


- HL-LHC Calorimeters

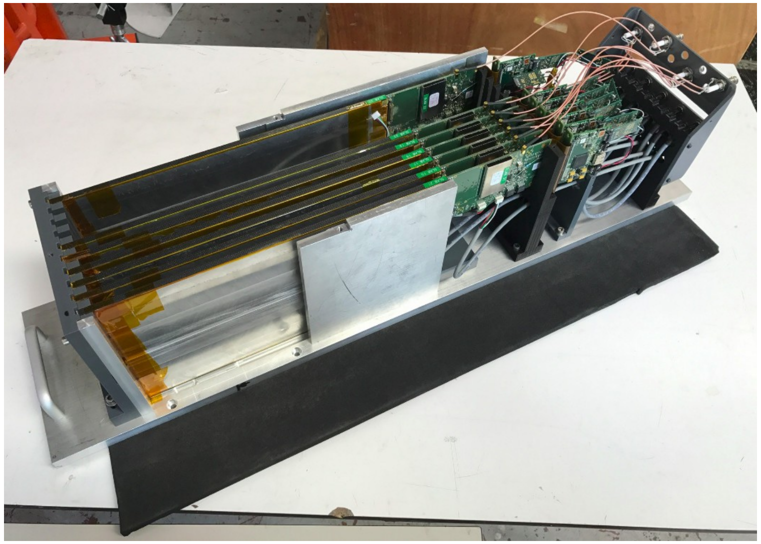
- Medical applications
  e.g. Endoscopie

Readout of “modern” calorimeters II - Semiconductor

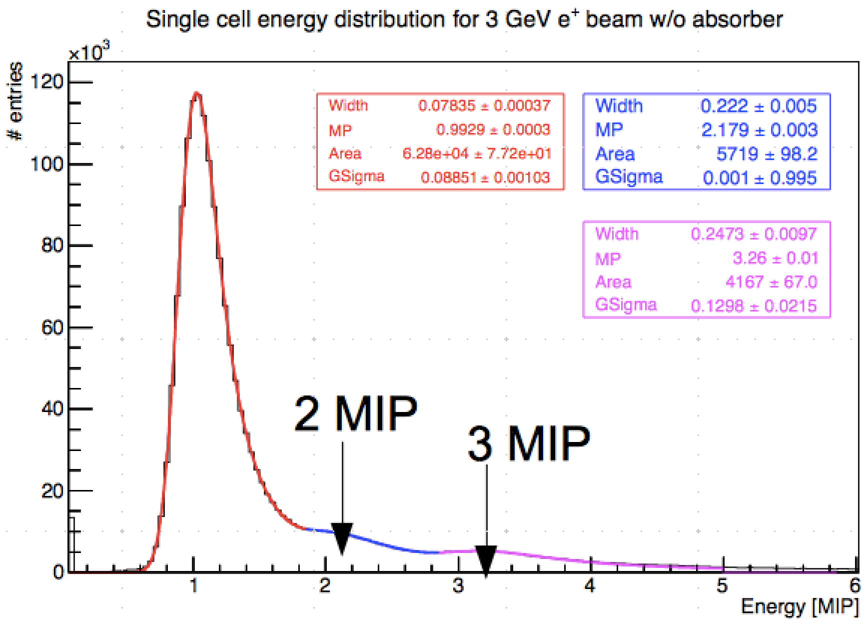
Si Wafer



Prototypes

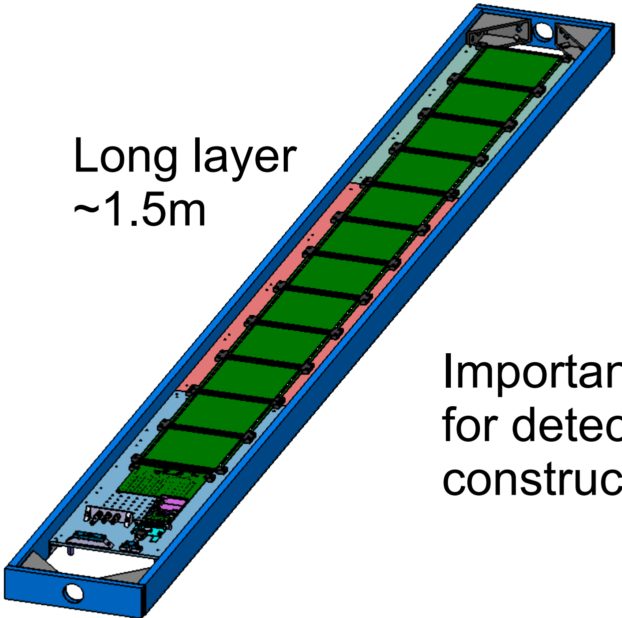


Test beams



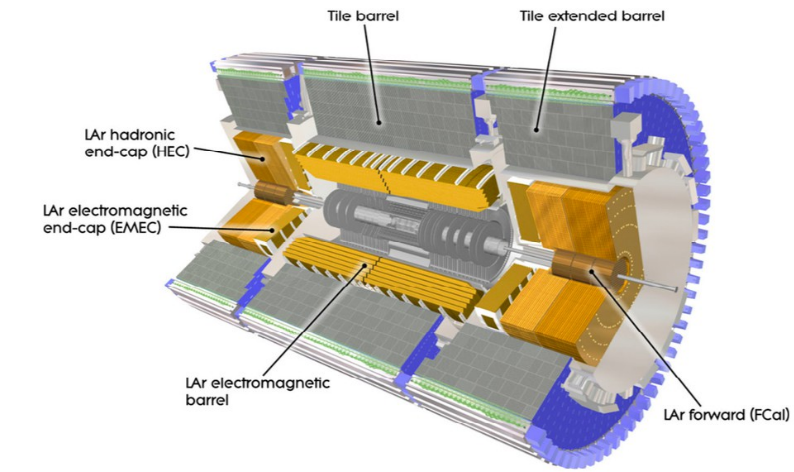
Real size layers

Long layer
~1.5m



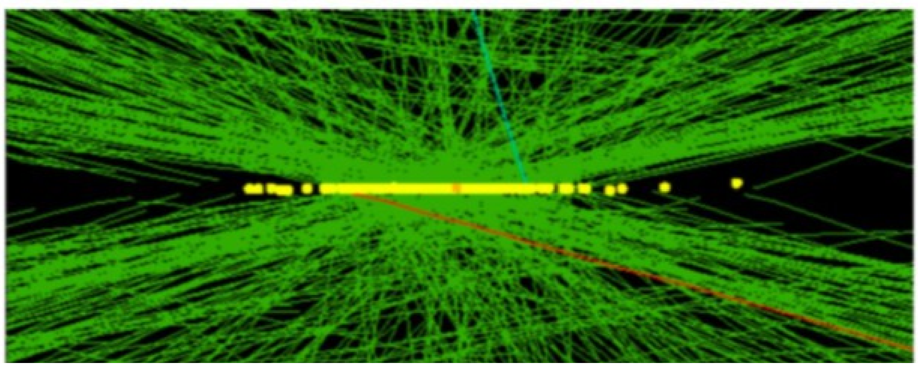
Important lessons
for detector
construction

Challenges @ high energy hadron colliders



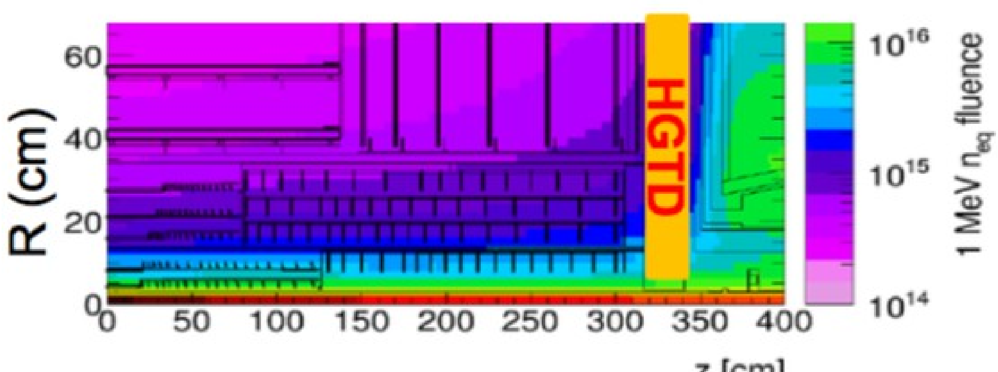
More energy:
Size of detector scales with energy
e.g. 100 TeV FCC-hh ~ 7x LHC
=> ATLAS-FCChh ~ 2xATLAS-LHC?

New absorber material?
New techniques to estimate shower energy?
Innovative mechanical structures?
Higher (alternative) magnetic fields?



78→200 PU → ??

Better pile-up mitigation?
More agressive timing – fs?
Where are limits?
Even higher granularity in calos
-> See later



Radiation levels
Even cooler environment
(e.g. HGCAL CMS operates at -30o)
Minimisation of occupancy?

- Which design is required by (potentially) new physics

Energy resolution of Si Detectors

A potential drawback may be the moderate electromagnetic energy resolution realistically achievable: $\Delta E/E$ 15 ~ 20% / $\sqrt{E}$

well matched to boosted kinematics of particles and jets in the End-Cap acceptance

but possibly sub-optimal for lower pT objects in central Barrel region

The EM energy resolution is strongly affected by Landau fluctuations of MIP energy deposits in the silicon

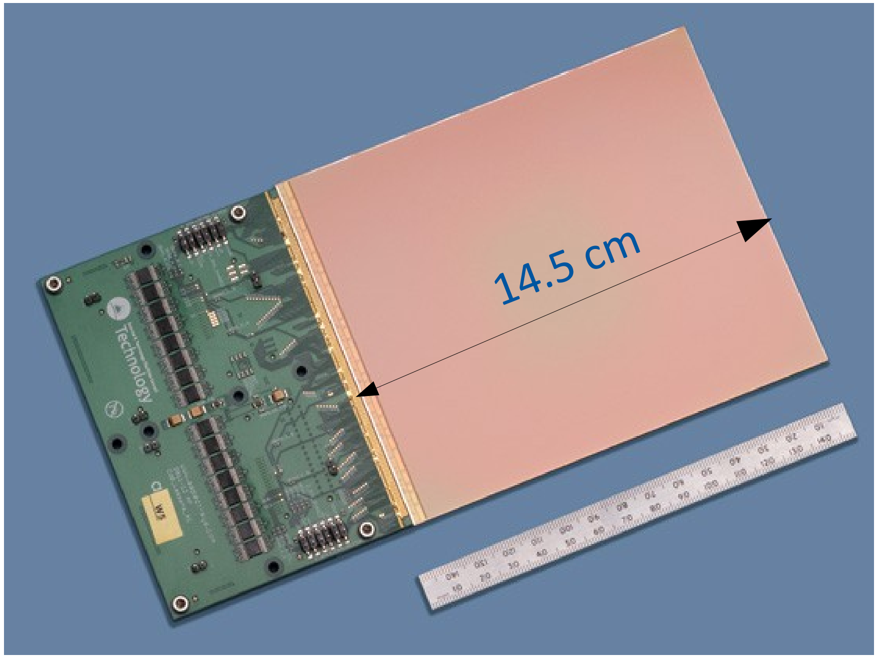
Directly counting MIPs may allow to substantially improve on this

Could MAPS detectors be a potential break-through for SiW calorimeters?

Potential for improved performance, reduced power, lower costs?

CMOS Pixel sensors

e.g ALPIDE Sensor for ALICE Tracker Upgrade: Pich 30x30 um^2



Courtesy: N. Guerrini Rutherford Appleton Laboratory

Terachannel calorimeters???

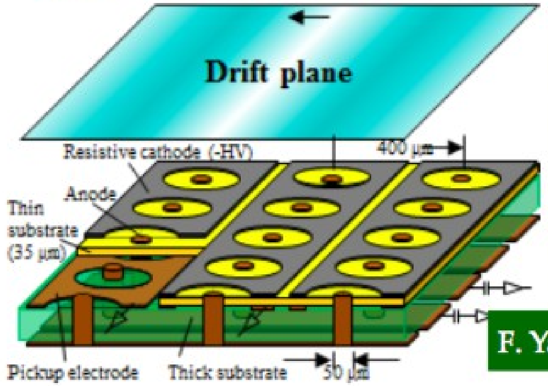
Wafer-scale integration possible due to stitching

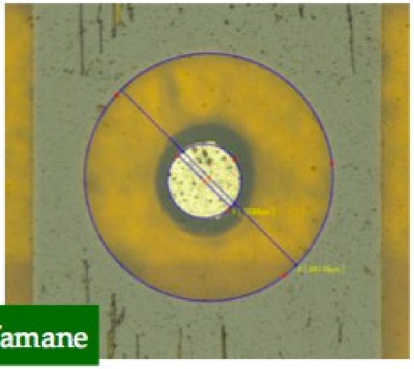
- Would ease assembly of large areas
- Has serious design implications
- One fab in a foundry: 1Mwafers/year, for ALICE (10 m2) 1.4 kwafers (200 mm), volume capability ok even for significantly larger areas

Micro Pattern Gas Detectors

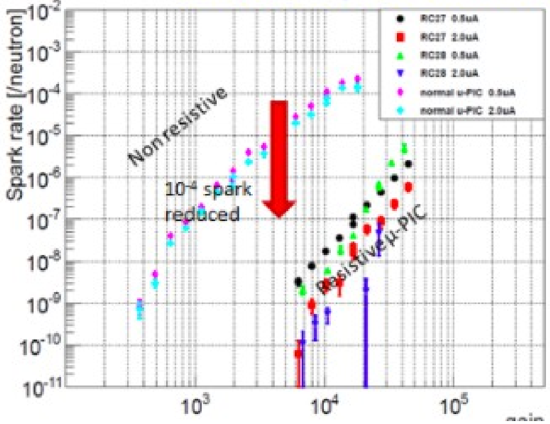
- Proposed for Phase II upgrade (~2023)
- Need high granularity ~ 0.1mm
- BG rate > 100kHz/cm² (HIP, gamma)
- Rate tolerant, Pixel type detector needed

μ-PIC with resistive Diamond-LC electrodes:

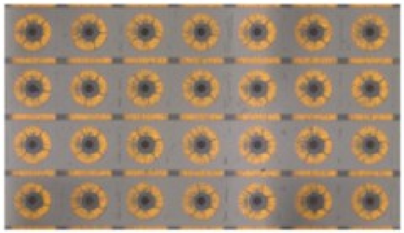




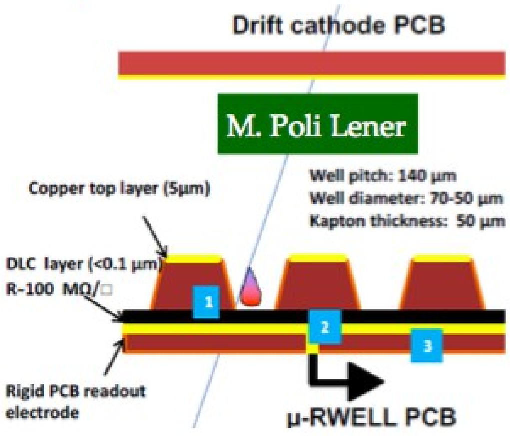
Spark rate reduction using resistive μ-PIC for fast neutron

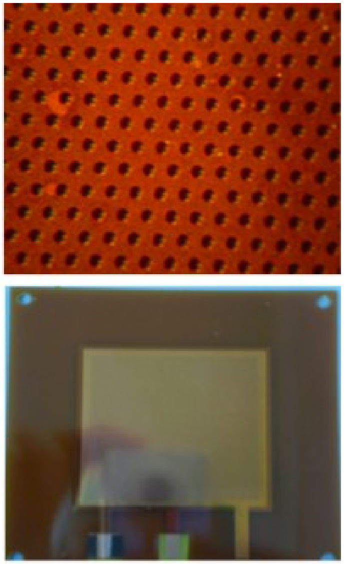


Resistive μ-PIC using sputtered C:

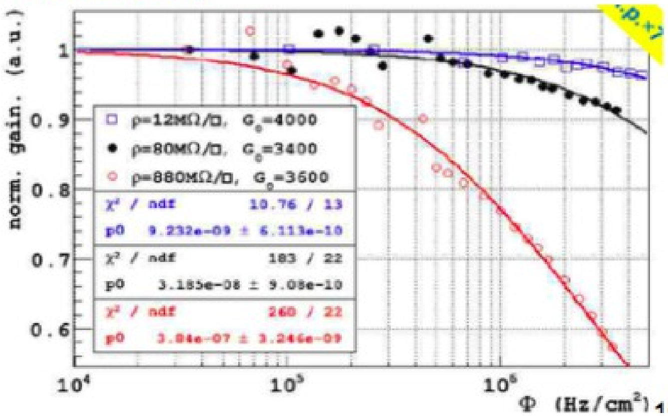


μ-RWELL Detector:





- Very reliable
- Almost completely *discharge-free*
- adequate for high particle rates O(1MHz/cm²) thanks to the *segmented-resistive-layer*
- suitable for large area applications (1.8 x 1.2 m² proto was tested in 2017)



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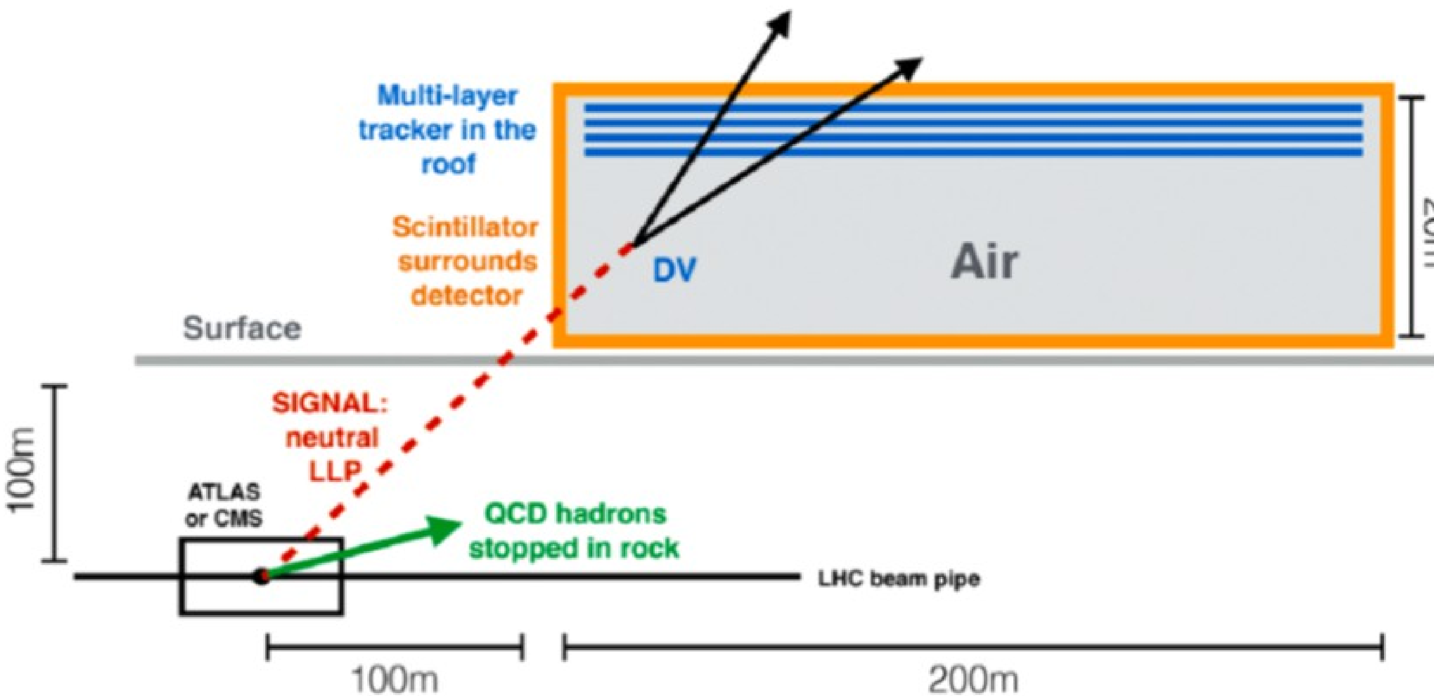
MAssive Timing Hodoscope for Ultra-Stable NeutraL PArticles



Baby Mathusla

Hands on experience for young students and postdocs

Backup